DETECTION OF HASTY STATE BY MEANS OF USING PSYCHOSOMATIC INFORMATION

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Abstract: We introduced an Internet survey and analyzed driver's psychosomatic state immediately before traffic incident by using 7 models of traffic accidents. We identified driver's hasty is one of key factors which may result in traffic accidents. Aiming at the reduction of the number of traffic accidents, we studied to detect hasty state of a driver while driving by way of using the psychosomatic signals of a driver, which were heart rate and useful field of view. Finally we proposed a concept of a function for detecting driver's states for an intelligent drive support system.

1 INTRODUCTION

The number of traffic fatalities in Japan as of 2010 has declined lower than 5,000 for two years, meanwhile the number of traffic injuries has still remained some 0.8 million (Cabinet Office, Government of Japan, 2011). Reducing the number of road traffic accidents is said as one of major challenges for the creation of sustainable mobility society. It is said that the above reduction has been brought by installation of airbag system and seatbelt into vehicle, enhancement of crashworthiness of vehicle, intensive enforcement of the Road Traffic Law (forbidding drunken drive, etc.) and effective education. Preventive safety may be one of important measures to reduce the number of traffic accidents, which have been studied globally in academia and automobile industries and developed into production vehicles such as electronic stability control system, blind spot detection system, and pre-crash safety system with functions that detect direction of a driver's face movement and eye movement (Ohue, 2006). AS main cause of traffic accidents is thought to human factors (Klauer, 2004), driver's state adaptive function into an intelligent drive support system which detects driver's psychosomatic states may enhance performance to lower a risk to be involved in a traffic accident.

Accident investigation and analysis is regarded as effective for helping to reduce traffic accidents. It is stated that in addition to investigation and analysis of traffic accidents, other important issues include understanding the human factors involved in traffic accidents, as well as investigation and analysis of traffic incidents to detect the signs of an imminent accident (The expert committee for safety engineering in Japan, 2000).

In our study we identified driver's hasty is one of key factors which may result in traffic accidents by way of Internet survey where we applied 7 models of traffic accidents used in third phase ASV promotion program in Japan (Toji, 2006). When driver is in a hasty state, we thought that it might affect driver's visual task of looking far forward and peripheral vision, which causes limitation of useful field of view (hereinafter; UFV) .

Previous study indicates that visual load affected driving performance (Engström, 2005), and eye-movement were highly sensitive to the demand of visual tasks while driving (Victor, 2005). With regard to UFV many studies have been carried out, of which is statistically reported that both UFV and mental states affected on crash frequency, which indicates prediction of crash problems in the elderly is available (Ball, 1993). Reduction of UFV by 40% increases the potential risk of being involved in a traffic accident (Owsley, 1998, Sims, 2000,

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Allahyari, 2007). Relation between UFV and other test have been statistically studies to apply on-road testing (MYERS, 2000, Roge, 2005, CLAY, 2005).

Therefore we studied to detect the hasty state of a driver while driving by means of using the psychosomatic signals such as heart rate and UFV. In order to establish the methodology to detect the states, we used a mock-up type driving simulator (hereinafter; DS). Finally we proposed a concept of a function to detect driver's psychosomatic states for an intelligent drive support system.

2 INCIDENTS AND INVESTIGATION AREA

2.1 Investigation Area

The methods used for previous analysis of traffic incidents involved drive recorders, which are triggered by sudden braking and therefore operated in areas of apparent risk when an accident is relatively close at hand. We expanded the survey area shown in Fig. 1 to include an area of potential accident risk. Traffic incidents are defined as circumstances in which the driver's vehicle seemed likely to strike another vehicle or a pedestrian. As previous analysis did not include analysis of driver's psychosomatic states, we collected information concerning traffic incidents which occurred during ordinary driving by means of a questionnaire survey, regardless of whether or not the brakes were operated. We defined seven traffic incident models of potential risks as right turn, crossing path collision, person to vehicle, head on collision, rear-end collision, left turn and lane change, which were used as traffic accident models in the Phase 3 ASV Promotion Project of Japan in 2006 (Toji, 2006).

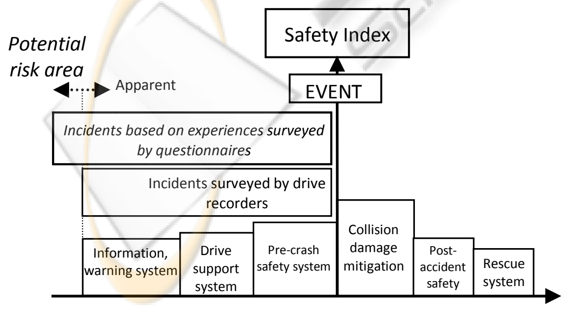

Figure 1: Investigation area

2.2 Investigation Method, Applicants

We introduced the preliminary survey to check any problem of misunderstanding and wrong answer for our intention on particular questions. We sent our questionnaire to candidate applicants by controlling our delivering system to avoid the deviation in gender, age, drive career and residential area, which were consisted of seven sections based on traffic incident types, with 19 questions concerning driver behaviours (no safety confirmation, inappropriate assumption, careless driving, etc.) and ten questions concerning psychosomatic states (haste, distraction, drowsiness, etc.) immediately before a traffic incident occurred per incident type. After an explanation, applicants answered questions with regard to traffic incidents which they encountered in the last two or three years using a questionnaire that included illustrations of accident types. A total of 2,000 subjects consisting of 1,117 male and 883 female between 19 and 69 years old were responded for the web survey. The average age was 41.6 years old and the average driving experience was 19.9 years. A 2.2% sampling error used statistical formulas was found for the questionnaire items. This sampling error value falls within the 1 to 3% range used for investigations conducted by Japanese government agencies and appears to be reasonable.

2.3 Traffic Incidents

Traffic incident types obtained by the Internet survey were crossing path (17.5%), lane change (15.9%), left turn (12.8%), right turn (12.1%), and rear-end collision (10.7%) in descending order of frequency, while those released by the National Police Agency as of 2006 were rear-end collision (31.3%), crossing path (27.0%), right turn (9.1%), and pedestrian (8.8%). Results of the Internet survey indicated that the seven incident models account for 86% of traffic accidents of real fields according to report of Japanese Police Agency.

2.4 Psychosomatic State

Psychosomatic states immediately before traffic incident obtained by Internet survey were haste (22%), distraction (21.9%), and normal (15%) in descending order of frequency shown in Fig. 2.

From the results, it is clear that haste and distraction are key factors of psychosomatic states immediately before traffic incident in consideration of driving areas that hold potential risks for accidents, and these factors should be addressed in order to help reduce traffic accident.

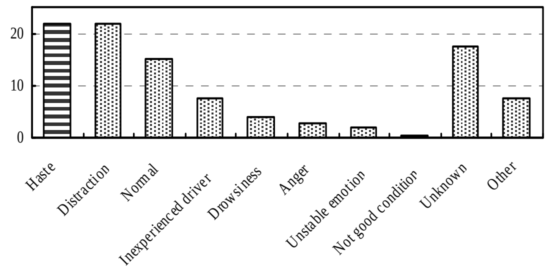

Figure 2: Driver's psychosomatic states

3 REPRODUCTION OF DRIVER'S HASTY STATE

When a driver is in a state of hasty by mental loads such as rush driving to a destination, its influence may appear in heart rate by acceleration of the sympathetic nerve, and leads pupil dilating, eventually, reducing the gaze angle of a driver. Furthermore it may increase potential risk of being involved in a traffic accident. Because concentrated gaze angle a driver while driving may be related to the decrease of UFV, capturing the changes of both heart rate and UFV of a driver may have possibility to detect driver's hasty state.

3.1 DS and Experiment

We used a stereo camera based tracking unit (the seeing machine's faceLAB) shown in Fig.3, and DS with a driving course of six scenes of traffic incident shown in Fig.4 and Table1 for reproduction of driver's hasty states while driving.

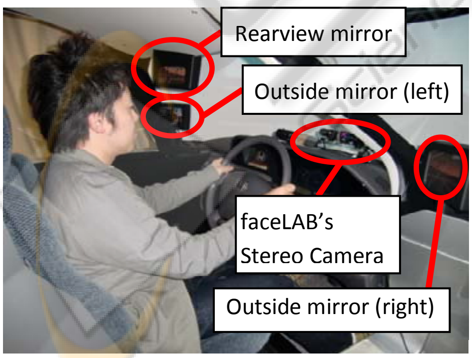

Figure 3: Driving simulator.

The stereo camera system with a 60 Hz frame rate and an information processing unit of gaze angle and direction was fitted at the top of the dashboard. The DS was equipped with left and right outside mirrors and a rear view mirror. A projector was installed in the ceiling of DS to picture a driving course onto the frontal screen. The distance of the driving course was 1.2 kilo-meters. The number of the subjects was 5, which age was between 20 - 57 years old.

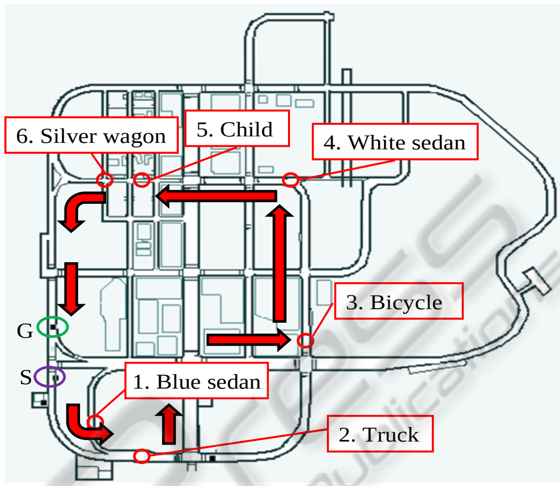

Figure 4: Driving course.

Table 1: Traffic incident scenes.

Scene No.	Traffic incident scenarios
1	Blue sedan merges into the driver's lane from the right
2	Truck merges from the left and turns right
3	Bicycle suddenly appears from behind a car and crosses the road from the left
4	White sedan merges into the driver's lane from the right
5	Child suddenly appears from behind a car and crosses the road from the left
6	Silver wagon suddenly appears from behind a fence and crosses the intersection from the left

After learning themselves with the DS for about an hour, the subjects were instructed to run the following sequences; twice ordinary driving, once hasty driving, and 5 minutes rest in between each driving. We instructed the subjects to drive faster for the hasty driving duration than for the ordinary driving duration in order to reproduce the hasty driving state, where the subjects took safety actions on their own judgment basis. Due to the specification of the DS, in the event of an accident such as a near-miss crash occurred with another vehicle along the course, the driving was compulsory stopped and the system promptly returned and restarted the course from a nearby position.

3.2 Gaze and Head Direction

The gaze and head direction are both output as vertical rotation "pitch angle θ" components (Up direction = Positive) and a lateral rotation "yaw angle ϕ" component (Rotation in a left direction = Positive) as shown in Fig.5. Other information obtained from the tracking unit included eye position, gaze direction, head position, head orientation angle, heart rate, driving time as well as counter force of brake pedal.

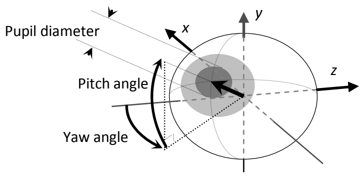

Figure 5: Pitch angle and yaw angle.

3.3 Heart Rate

We measured an electrocardiogram (hereinafter; ECG) waveform by the monitor lead method, involving standard limb lead (II) and measurement with 3 chest electrodes as shown in Fig.6. Using a poly-mate AP1000 (DIGITEX Lab. Co., Ltd), we obtained ECG, and removed ripple noise from the waveform by using 4th butter-worth band pass filters, of which sampling rate was 60 Hz with 5 seconds time window.

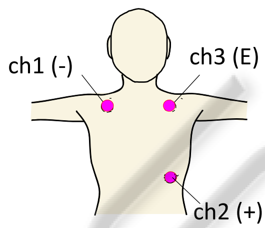

Figure 6: Measurement of ECG.

3.4 Measurement of UFV and Gaze Time

We analyzed a still picture from the recorded movie of the tracking unit at the frame rate of about 20 fps with regard to eye position, gaze direction, head position, and head direction, driving time as well as heart rate. When a moving object appeared in the peripheral field, a extent of viewing angle of central vision field in the width of ±6.5 degree (hereinafter; 13 degree) in lateral rotation moved to the moving object and contact it instantly. We defined an amount of change of gaze angle in yaw component was as "UFV", and an amount of the change of time was defined as "gaze time".

3.5 Calculation of UFV and Gaze Time

We calculated UFV and gaze time as follows. Firstly the extent of viewing angle of central vision field was put as 13 degree. When a part of moving object is contacted in the viewing angle of central vision field, the state of the driver is defined as onset of gazing at the moving object. Then the extent of viewing angle of central vision field is transformed into (u^+, v^+) or (u^-, v^-) , which are coordinate of the tracked picture by using formula (1), (2), (3), (4), (5) and (6). The subscripts used in the formula are defined as following; r indicates datum of right eye, l indicates that of left eye. c_r and l_r indicate reliability factor of output datum of the tracking system (faceLAB) for right eye and left eye respectively. **e** indicates the position of eyeball. **p** indicates coordinates of the gaze point. λ indicates constant number. **M** indicates the matrix of projective transformation.

$$\bar{\mathbf{d}}^+ = \frac{1}{c_r + c_l}\left(c_r \begin{bmatrix} -\sin(\phi_r - 13)\cos(\theta_r) \\ -\sin\theta_r \\ -\cos(\phi_r - 13)\cos(\theta_r) \end{bmatrix} + c_l \begin{bmatrix} -\sin(\phi_l - 13)\cos(\theta_l) \\ -\sin\theta_l \\ -\cos(\phi_l - 13)\cos(\theta_l) \end{bmatrix} \right) \quad (1)$$

$$\bar{\mathbf{d}}^- = \frac{1}{c_r + c_l}\left(c_r \begin{bmatrix} -\sin(\phi_r + 13)\cos(\theta_r) \\ -\sin\theta_r \\ -\cos(\phi_r + 13)\cos(\theta_r) \end{bmatrix} + c_l \begin{bmatrix} -\sin(\phi_l + 13)\cos(\theta_l) \\ -\sin\theta_l \\ -\cos(\phi_l + 13)\cos(\theta_l) \end{bmatrix} \right) \quad (2)$$

$$\mathbf{p}^+ = \lambda\bar{\mathbf{d}}^+ + \bar{\mathbf{e}} \quad (3)$$

$$\mathbf{p}^- = \lambda\bar{\mathbf{d}}^- + \bar{\mathbf{e}} \quad (4)$$

$$\begin{bmatrix} u^+ & v^+ & 1 \end{bmatrix}^{\mathrm{T}} \approx \mathbf{M}_l^+ \begin{bmatrix} p_x^+ & p_y^+ & p_z^+ & 1 \end{bmatrix}^{\mathrm{T}} \quad (5)$$

$$\begin{bmatrix} u^- & v^- & 1 \end{bmatrix}^{\mathrm{T}} \approx \mathbf{M}_l^- \begin{bmatrix} p_x^- & p_y^- & p_z^- & 1 \end{bmatrix}^{\mathrm{T}} \quad (6)$$

Then the coordinate of moving object in the tracked picture is put as (u_{ob}, v_{ob}). When u_{ob} complies a condition in the formula (7), a state of the driver is defined to gaze at the moving object shown in Fig.7.

$$u^- \le u_{\mathrm{ob}} \le u^+ \quad (7)$$

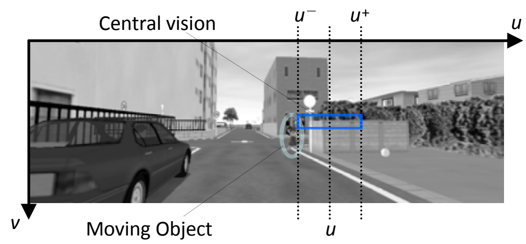

Figure 7: Relation ship between central vision and gaze of a driver.

Secondly t_{ap} is defined as appearance time when a moving object appears in the peripheral field, ϕ_{ap} is defined as yaw angle in lateral component of driver's gaze direction at that time. Meanwhile tat is defined as gaze time when the driver gazes at the moving object. Accordingly ϕ_{at} is defined as yaw angle in lateral component of driver's gaze direction at that time. Furthermore T [sec] is defined as gaze duration of time between appearance time of the moving object and gazing time (hereinafter; gaze duration), and change of gaze angle is defined as Φ [degree] as UFV followed by formula (8) and (9). Hereafter we used the indexes to examine driving time, heart rate and UFV.

$$T = t_{at} - t_{ap} \tag{8}$$

$$\Phi = \left| \phi_{at} - \phi_{ap} \right| \tag{9}$$

4 RESULTS OF EXPERIMENT

4.1 Driving scene of Traffic Incident

Six driving scenes of ordinary driving and hasty driving were indicated in Fig.8. A blue rectangle in the picture indicates viewing angle of central vision field in lateral rotation, which was derived from the yaw angle of gaze direction of the tracking unit. Red rectangle indicates that of head direction. Each picture includes superposed five frames of blue and red rectangle, which was superposed by past two frames to post two frames including present frame for the capture of the both movement of blue rectangle and red rectangle closely. The moment when the moving object contacted the vertical dotted lines such as u^+, or, u^- in Fig.7 was defined as onset of gazing. We measured appearance time of the moving object (t_{ap}), and gazing time (t_{at}) by means of analyzing the yaw angle data of the recorded video picture on manual procedure basis.

The measurement results for the gaze time and UFV of subject E are shown in Table 2 for the six traffic incident scenarios. For almost cases in hasty driving for the gaze to turn to moving objects was found to have tendency that are closer to the driver than in ordinary driving.

Table 2: Gaze time and UFV (subject E).

No.	Ordinary driving		Hasty driving	
	Gaze duration (sec)	Eccentricity (deg)	Gaze duration (sec)	Eccentricity (deg)
1	1.72	27.8	0.81	30.6
2	0.65	35.3	2.72	3.1
3	0.05	35.9	1.81	17.4
4	0.05	-7.5	0.00	-7.6
5	0.00	25.1	0.00	30.7
6	2.38	21.4	2.16	27.2

4.2 Heart Rate and Drive Time

Results of the change of heart rate between hasty driving and ordinary driving was shown in Fig. 9.

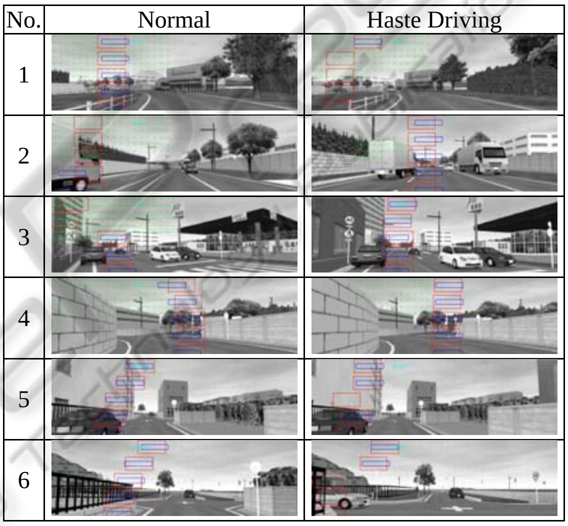

Figure 8: Measurements results for subject E.

Heart rate in hasty driving was higher than ordinary driving in all the subjects. The results agreed with previous study (Kahneman, 1969). Furthermore the counter force of brake pedal in hasty driving indicated stronger than that of ordinary driving. This verified that the subjects were fallen in the state of tense by hasty driving.

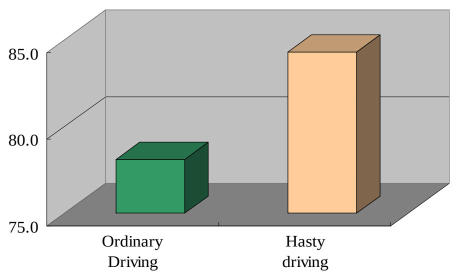

Figure 9: Heart rate change (Unit: beats/min).

Results of the change of total driving time between hasty driving and ordinary driving were shown in Fig.10. When the subjects ran a hasty driving, the driving time became shorter than that of ordinary driving.

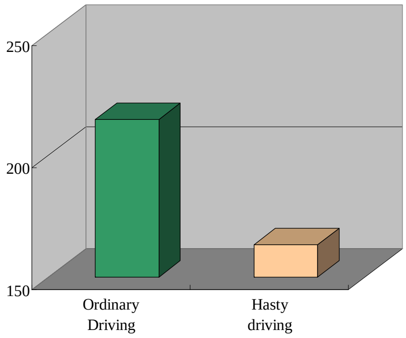

Figure 10: Driving time (Unit: sec).

4.3 Counter Force of Brake Pedal

Results of the change of counter force of brake pedal between hasty driving and ordinary driving shown in Table 3.

Table 3: Counter Force of Brake Pedal.

Subject	Ordinary driving (kgf)	Hasty driving (kgf)
A	22.0	57.1
B	22.1	43.4
C	18.5	32.7
D	11.8	27.3
E	19.2	27.9

Counter force of brake pedal of the all subject increased in all scene of the hasty driving. The above result indicates the subjects had tendency to take stronger braking to avoid unintended collision when they recognized the moving objects encountered in the hasty driving. From the results, it is said that the method of this study reproduced hasty driving in the driving course

4.4 Gaze Duration and UFV

Results of the change of gaze duration and UFV (indicated as Eccentricity) between hasty driving and ordinary driving shown in Table 4. UFV of the all subject decreased in all scene of the hasty driving. Accordingly gaze duration was mostly prolonged in hasty driving except subject C. It is said that the potential risk of being involved in a traffic accident increases when a driver runs a hasty driving because of decreasing concentration to surroundings of the vehicle caused by a narrower UFV. From the results capturing the change of UFV may indicates a potential risk of being involved in a traffic accident.

Table 4: Gaze time and Eccentricity.

Subject	Ordinary driving		Hasty driving	
	Gaze duration (sec)	Eccentricity (deg)	Gaze duration (sec)	Eccentricity (deg)
A	1.46	16.8	1.67	14.7
B	1.40	16.0	1.59	14.4
C	1.55	18.2	1.29	10.6
D	0.25	26.4	0.81	23.9
E	0.81	24.3	1.25	16.9

5 POTENTIAL DRIVE\ING SUPPORT SYSTEM

We identified the relationship in a particular combination among driver's behaviour, driver's psychosomatic states and expected intelligent safety systems derived from our survey shown in Table 5. To illustrate the function, for example, a driver's psychosomatic state monitoring system could detect a state of hasty driving as well as insufficient recognition of a driving environment. Upon detection, the system could provide appropriate information to the driver, to give warnings, or to intervene in the driver's operation in order to help minimize the risk of incidents in combination with information surrounding the vehicle provided by the surrounding monitoring system. If the driver's psychosomatic state is normal but driver makes inappropriate assumptions while driving, traffic safety information from road infrastructures such as represented by ITS services (VICS in Japan) and the driving safety support system (DSSS in Japan) could be employed. The realization of intelligent drive support systems activated by detecting driver's psychosomatic states is expected as one means to help minimize road traffic safety risks.

Table 5: Expected intelligent safety system.

Driver's behaviours	Driver's psycho-somatic states	Expected intelligent safety system
In-appropriate assumption	Normal	(1) Providing information from the roadside infrastructure
		a) ITS services (AHS)
		b) Driving Safety Support Systems (DSSS)
		c) Traffic information collected by prove cars
	Haste	(2) Monitoring of surroundings
	Distraction	a) Pre-crash safety system
No safety confirmation	Haste	b) Night view system
	Distraction	c) Rear-end monitoring system
Desultory driving	Distraction Drowsiness	d) Side-view monitoring system (Blind spot monitoring)
		(3) Driver psychosomatic states monitoring
Not look ahead carefully	Distraction	a) UFV detection
		b) Driver's drowsiness detection
		c) Driver's distraction detection

From the results, it is clear that in addition to providing support for recognizing potential risks in the driving environment during ordinary driving, future intelligent drive support systems could detect driver's psychosomatic information in real time, and effectively provide support for correct driving decisions and carry out intervention into vehicle control system. Fig. 11 shows the functional concept for such an integrated intelligent drive support system.

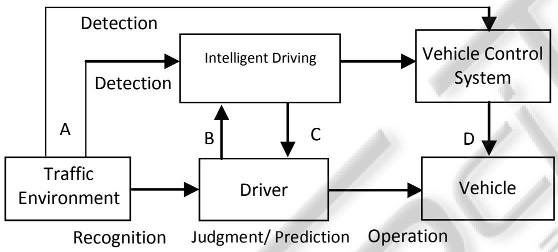

Figure 11: Intelligent drive support system.

The system works as follows;

A. Detect and estimate risk factors in the environment.
B. Detect and estimate a state of the driver with regard to driver's behaviour and psychosomatic states (hasty driving).
C. Estimate the reliability of the driver's decision concerning risk (presence of human error).
D. Evaluate the driver capacity for receiving information and warnings. If a driver's capacity is insufficient or the danger exceeds the human ability to react, the intelligent drive support system intervenes, either via the vehicle control system or directly, to operate the vehicle safety systems.

6 SUMMARY, FUTURE ISSUES

We introduced Internet based survey with regard to traffic incidents and identified driver's psychosomatic states while driving. Then we studied the method to detect driver's psychosomatic states by means of measuring the change of heart rate in ECG and UFV. The following was revealed;

- Internet survey using questionnaire may be one of effective means to collect information with regard to traffic incidents
- Hasty driving is one of key factors of human errors which likely being involved in traffic accidents.
- Hasty driving may be detected by means of capturing the change of heart rate and UFV.
- Driver's psychosomatic states adaptive intelligent drive support system may have potential ability to help minimize the potential risks of encountering traffic accidents such as hasty driving as well as driver's distraction.

Future issues include further enhancing the performance of detecting driver's hasty driving by means of introducing three dimensional visual field tracking unit to detect the distance of the moving object and improving the method of determining of the onset of the gazing as well as realization of s driver's hasty driving monitoring function for the intelligent drive support system for the reduction of the number of traffic accidents.

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