Development of Driver Distraction Control Function

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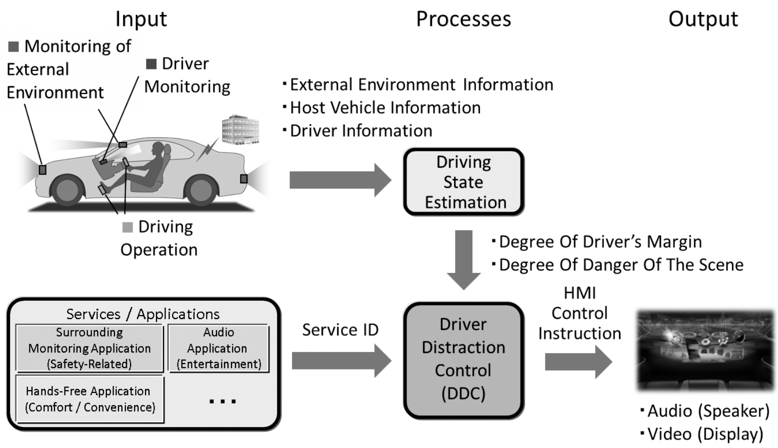


Abstract

Recently, people have gained an increasing amount of information even in vehicle thanks to the more sophisticated Internet and rapid spread of information terminal devices. Thus, a variety of information and service will continue to be provided to drivers in vehicle, via the Internet. However, unlimited service provided to drivers while driving a vehicle may cause Driver Distraction (DD) and they may be unable to concentrate on driving. As a result, in contradiction to purposes of the service designed to improve comfort and convenience of the drivers, the service may interrupt their safe driving and thus it poses a problem that safety of the drivers may not be ensured. We developed Driver Distraction Control (DDC) that controls the DD from the driving state analyzed based on information estimated from the external information, host vehicle information and driver information because we believed that we needed to control the DD to solve the problem. This paper elaborates on development of DDC, its vehicle-mounted test to check usability, the evaluation results from the test and its challenges.

1 Introduction

With the more sophisticated Internet and rapid spread of information terminal devices, needs for supply of information in vehicle have arisen, and an increased number of services have become available to drivers in vehicle. Furthermore, automobiles are connected to the society over the Internet, and it is expected that various kinds of service using networks will be more available.

However, unlimited services provided only in consideration of comfort and convenience for drivers while driving may cause Driver Distraction (DD) and the drivers may be unable to concentrate on driving, hindering their safe driving. The occurrence of DD is a problem involving the whole automobile industries, National Highway Traffic Safety Administration (NHTSA) established Human Machine Interface (HMI) guideline[1)] for the purpose of control of DD in April, 2013 and determined to restrict services and vehicle-mounted devices which do not comply with the rules provided in the guideline in the U.S. In view of this, similar regulations will be provided in Japan in near future, and a rapid response to this movement may be required.

From this, safety while providing services to a driver must be guaranteed by automobile manufacturers. In order to solve problems associated with the safety while providing services to a driver, we believed that we needed to develop Driver Distraction Control (DDC) that controls the DD based on the driving state by controlling information supply to a driver. Therefore, we developed DDC.

2 Driver Distraction Control (DDC)

2.1 DDC General Processing

This section will describe processing of DDC that we are aiming at and HMI control examples. **Fig. 1** illustrates an HMI control process by DDC.

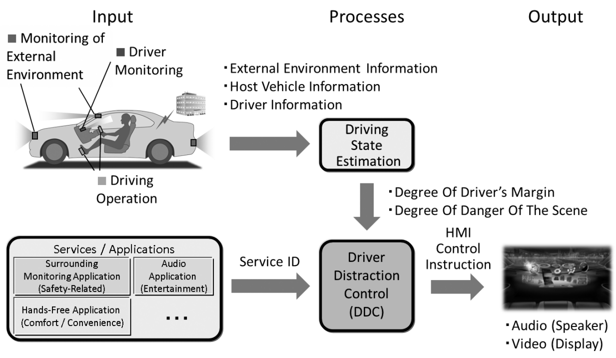


Fig.1 Flow of HMI Control Process by DDC

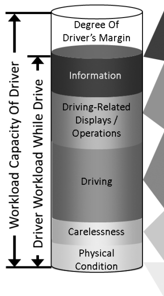
HMI control by DDC that we are aiming at acquires three kinds of information: external environment information, host vehicle information and driver information as inputs. A driving state is estimated based on those acquired three kinds of information, and degree of driver's margin of a driver (degree of concentration to driving) and a degree of danger of the scene (potential degree of danger of accident in outside situation) are output to DDC. Furthermore, a service ID of a service/application is input to DDC, and optimum type of information and optimum amount of information in consideration of driver's driving state are determined. Then, an HMI control instruction is output. An output device (such as a speaker and a display) in response to the HMI control instruction notifies a driver of the optimized information.

The information to be acquired as inputs during processing for estimating a driving state will be described. The term "external environment information" refers to environment information regarding surroundings of a vehicle acquired from sensors which monitor an outside situation of the vehicle by using a camera and a millimeter wave radar as well as information acquired from the outside of the vehicle such as traffic congestion information acquired through an external infrastructure and information regarding incident-related-points present on a driving route. The term "host vehicle information" refers to information regarding a vehicle speed, a steering angle and a yaw rate communicated over a Controller Area Network (a standard for data transfer between devices: CAN) to which electronic circuits and Electronic Control Unit (ECU) within a vehicle are connected. The term "driver information" refers to information dependent on a driver such as driver's look away, look aside and sleepiness acquired by monitoring the driver through sensors for driver's gaze, orientation of face and heartbeat rate. We believe that use of the three kinds of information thus acquired can provide driving state estimation supporting various driving states.

Next, the degree of driver's margin and the degree of danger of the scene which are calculated as an output in the processing for driving state estimation will be described. The degree of driver's margin defined by us can be calculated by Expression (1):

Degree of driver's margin =
Workload capacity − Workload of a driver while driving (1)

The workload capacity in Expression (1) is defined as information which can be recognized and judged by a driver while driving and the total amount of operation. The workload of a driver while driving is defined as information recognized and judged by a driver while driving and the amount of operation. **Fig. 2** illustrates workload of a driver while driving and information necessary for workload estimation.



Workload Of Driver While Driving	Information Necessary For Workload Estimation	Definition Of Distraction (NHTSA)
-Entertainment Information (Excluding Running, Turning And Stopping) -SNS (Text), Music, Look-Aside	Driver Information	•Visual •Manual •Cognitive
-Displays / Operations On Vehicle-Mounted Device Associated With Running, Turning And Stopping -Route Indication, Navigation Operations	-Host Vehicle Information -Driver Information	•Visual •Manual
-Driving Operations Associated With Running, Turning And Stopping -Steering, Braking, Acceleration Operations	-Host Vehicle Information -External Environment Information	−
-Indications Of Mental Conditions-Dull, Thinking About Something, Irritated, Impatient	Driver Information	Cognitive
-Indications Of Physical Conditions -Tired, Sleepy, Sick	Driver Information	−

Fig.2 Workload of Driver While Driving Car and Information Necessary for Workload Estimation

It is defined that the workload of a driver while driving includes five items of information workload, driving-related display / operation workload, driving workload, careless state, and physical condition. We considered that estimation of all of those items provides highly accurate estimations of the workload of a driver while driving and the degree of driver's margin. The workloads (information workload, driving-related display / operation workload, and careless state) defined by us internally contains three categories (Visual Distraction, Manual Distraction and Cognitive Distraction) of DD defined by NHTSA, and the effectiveness with respect to DD control could be verified.

The degree of danger of the scene is calculated by Expression (2):

Degree of danger =
Actual degree of danger + Potential degree of danger (2)

The actual degree of danger in Expression (2) is defined as a degree of danger estimated mainly from external environment information such as the slipperiness of a road surface, risk of collision with surrounding vehicles, and others. The potential degree of danger is defined as a degree of danger estimated mainly from external environment information and host vehicle information such as incident-related-point information, vehicle speed information, and others. By adding these two degrees, the degree of danger of the scene is calculated.

In DDC, the degree of driver's margin and the degree of danger of the scene are combined with a service ID to determine information to be presented to the driver. The service ID is an ID by which a service/application, such as a surrounding monitoring application, an Audio application, and others to be presented can be identified.

Fig. 3 illustrates an example of HMI control determined by DDC.

Fig.3 Example of HMI Control by DDC
(Left: without HMI Control Right: with HMI Control)

In-vehicle services currently available in the market present received information on a navigation display irrespective of the degree of driver's margin while driving and the degree of danger of the scene when it receives a notification not related to driving, for example, from a social networking service (SNS) as illustrated in **the left hand side of Fig. 3**. Because of this, information unnecessary for driving operations performed by the driver is provided as a result, and there is a risk that DD may occur due to the information workload.

On the other hand, as in the picture on **the right hand side of Fig. 3**, the amount of information that can be provided is calculated from the degree of driver's margin while driving and the degree of danger of the scene, and HMI control is executed in accordance with the amount of information. Thus, when a notification not related to driving is received from an SNS under the same circumstance as that in the picture on **the left hand side of Fig. 3**, the content of the SNS is not displayed to prevent occurrence of DD due to the information workload. Instead, a small indication of the receipt of the notification is displayed while an indication of warning that an interrupt vehicle is present in front of his/her host vehicle is largely displayed. After that, when it is determined that the degree of danger of the scene decreases, the content of the SNS is presented by the amount of information which does not cause driver's DD.

Implementation of HMI control using DDC allows control of DD and provision of more services than before without losing the safety, comfort and convenience.

2.2 Concretization of DDC

Fig. 4 illustrates a configuration of DDC internal processing.

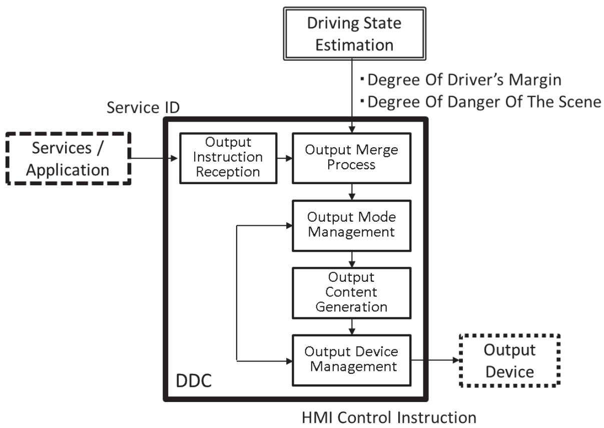


Fig.4 Internal Block Diagram of DDC Process

DDC includes five processes. First of all, an output instruction reception process in response to input of a service ID outputs an output instruction for a service to an output merge process. The output merge process in response to input of the degree of driver's margin, the degree of danger of the scene, and the output instruction for service determines the priority level, the amount of information to be provided, and output timing. The process further selects a presentation method suitable for the driver from the determined three types of information and outputs it to an output mode management process. The output mode management process determines the content to be output based on the presentation method suitable for the driver and the resource of the output device acquired from the output device management and outputs an instruction to generate it to an output content generation process. The output content generation process in response to input of the generation instruction generates the output content suitable for the driver and outputs it to an output device management process. The output device management process in response to input of the output content outputs an HMI control instruction to an output device. Output devices connected within the vehicle are recognized upon start of DDC, and the resource information is output to the output mode management process. These processes described above constitute DDC internal processing which implement control over the type and amount of information to be provided based on the driving state.

3 Construction of DDC

3.1 System Configuration

This paper explains the system development of a DDC using external environment information and host vehicle information. **Fig. 5** illustrates a configuration of DDC constructed in this system development, and **Fig. 6** illustrates the DDC system on a vehicle. For specific illustration of the device configuration for implementing DDC, different types of frame lines are used to indicate correspondences between processes in **Figs. 4, 5, and 6**.

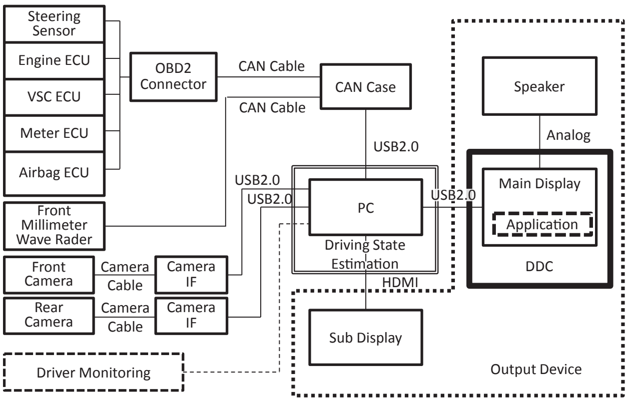


Fig.5 Block Diagram of DDC System

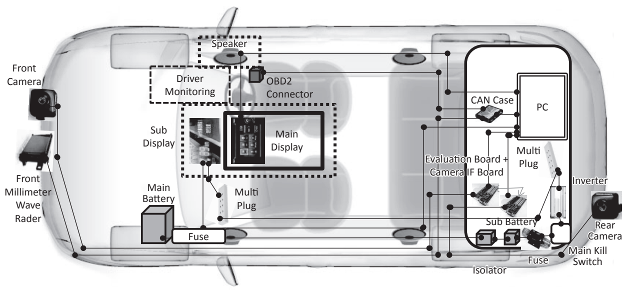


Fig.6 System Block Diagram on Vehicle

In the system constructed here, the degree of danger of the scene is only output as a result of driving state estimation to DDC. Though the degree of danger of the scene is still under review, the degrees of danger per scene and scenes expected from external environment information and host vehicle information are given in **Table 1**.

Table 1 Possible Scenes and Judging Criteria for Degree of Danger per Scene

Degree Of Danger Of The Scene	Expected Scene
1	Parked (Vehicle Speed 0 km/h)
2	Driving Slower Than 30 km/h, No Approaching Object
3	Driving Slower Than 30 km/h, Parked Vehicle Detected
4	Driving At 30 km/h Or Faster, Narrow-Road Detected
5	Driving At 30 km/h Or Faster, Approaching Object Detected

DDC was installed in a main display (mounted on a center panel of a navigation system or a display audio, for example) and was evaluated in an environment close to actual implementations. For visual presentation of information, a main display (**Fig. 7, top**) and a sub display (**Fig. 7, lower left**) were used. The main display was mounted on a center panel, and the sub display was mounted at the center of a dashboard. For acoustic presentation of information, vehicle-mounted speakers (**Fig. 7, lower right**) provided as standard equipment on the right and left front doors of the vehicle were used. As a processing unit for driving state estimation, a personal computer (or PC) was used.

Fig.7 Information Providing Devices

As the own vehicle information, CAN information was used which could be acquired by connecting On Board Diagnosis second generation (a vehicle self-diagnosis function : OBD2) connector in a driver's legroom to the PC via a CAN case. As the external environment information parked vehicle detection information, narrow-road detection information, and approaching object detection information acquired by front and rear cameras and a millimeter wave radar were used. This system applies a combination of cameras and a millimeter wave radar, aiming at low-cost detection of an object and a narrow-road instead of newly adding a dedicated sensor.

3.2 Information Content provided by Information Providing Device

3.2.1 Video Presentation

Video to be provided is controlled based on the degree of danger of the scene output from a PC. The contents to be provided are given in the column of Main Display and in the column of Sub Display column of **Table 2**.

Table 2 Displayable Information per Degree of Danger of Scene

Degree Of Danger Of The Scene	Main Display	Sub Display	Vehicle-Mounted Speakers
1	Display Of Music Play Screen	-Indication Of Surrounding Obstacle (Simplified Figure) -Indication Of Degree Of Driver's Margin	-Play Music (Normal Volume)
2	Display Of Music Play Screen	-Speed Indication -Indication Of Degree Of Driver's Margin	-Play Music (Normal Volume)
3	Display Of Music Play Screen	-Indication Of Surrounding Obstacle (Simplified Figure) -Indication Of Degree Of Driver's Margin	-Play Music (Volume Down) -Warning Sound (Normal Volume)
4	Display Of Limited Operation	-Indication Of Surrounding Obstacle (Simplified Figure) -Indication Of Degree Of Driver's Margin	-Play Music (Volume Down) -Warning Sound (Normal Volume)
5	Display Of Limited Operation	-Indication Of Surrounding Obstacle (Simplified Figure) -Indication Of Degree Of Driver's Margin	-Play Music (Volume Level: 0) -Warning Sound (Normal Volume)

The main display shows a screen indicating a state of limited operation when the degree of danger of the scene increases in addition to a content of a service and application conventionally displayed on the main display. **Fig. 8** illustrates an example of the screen indicating the state of limited operation, and touch operations on the main display are limited while the screen is being displayed. Display of such a screen as illustrated in **Fig. 8** in a scene with a high degree of danger can prompt a driver to concentrate on driving.

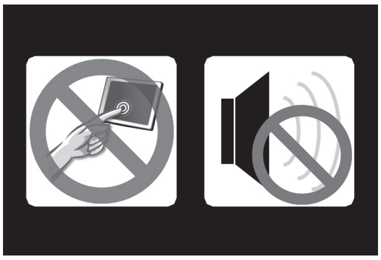


Fig.8 State of Limited Operation

The sub display shows a surrounding obstacle indication as shown in **Fig. 9**. The display contents change in real time in accordance with the degree of danger of the scene and an approaching object detection result. **Figs. 9 and 10** illustrates examples of the display contents including a combination of a circle displaying the degree of danger of the scene and an ellipse displaying an approaching object detection result. From the changing display contents, a driver can intuitively grasp the state where he or she is.

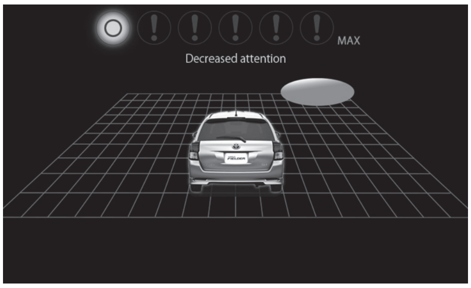


Fig.9 Surrounding Obstacle Presentation

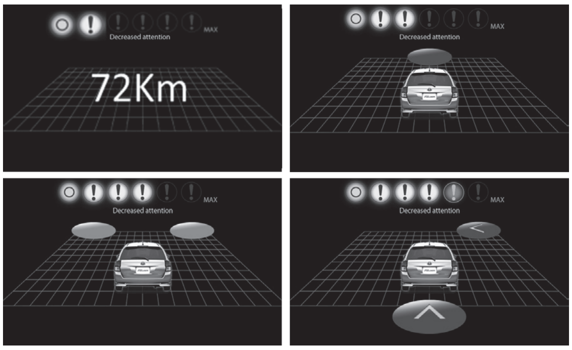


Fig.10 Examples of Surrounding Obstacle Presentation

This paper explains a system constructed by using a liquid crystal display as a sub display. However, there is an opinion that a head-up display (HUD) may be better to use in order to minimize the vision shift amount and interference with the view of a driver while driving. Accordingly, the system constructed this time supports such display on an HUD.

3.2.2 Audio Presentation

Contents to be presented by vehicle-mounted speakers in response to an instruction from DDC are given in the column of vehicle-mounted speakers in **Table 2**. A content of a warning sound is determined based on a detection result of external environment information and a warning sound "ATTENTION TO OBJECT APPROACHING FROM THE BACK" is output when a vehicle is approaching from the back, for example. When a narrow-road is detected, a warning sound "NARROW-ROAD AHEAD" is output. Giving an auditory warning in addition to a visual warning allows a driver to aware of a high degree of danger of the scene and prompts his or her concentration on driving.

4 DDC Usability Evaluation

4.1 Evaluation Method

DDC constructed as described in Section 3 was installed in a vehicle for evaluation for the purpose of check of the usability of DDC and extraction of problems. As a running test course for the evaluation, a street including a T junction and pedestrian crossovers illustrated in **Fig. 11** were selected so as to reproduce changes in degree of danger of scenes (see **Table 1**) defined by us. In order to achieve different degrees of danger of scenes, obstacles and a narrow-road were set in scene (1) to scene (5) in **Fig. 11**. **Table 3** chronologically illustrates dangerous situations in different scenes and different degrees of danger of the scenes.

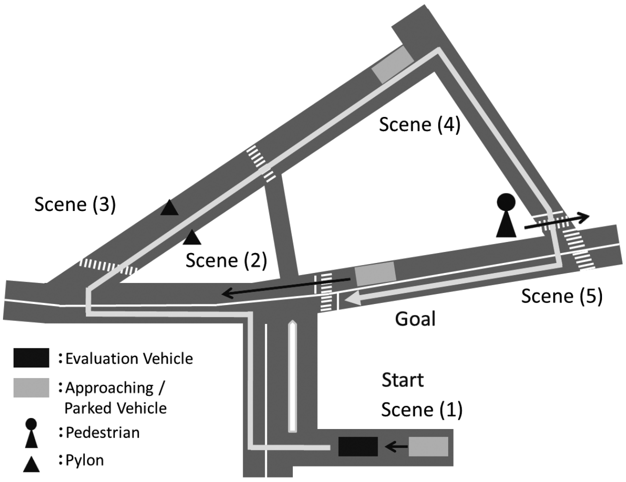


Fig.11 Running Test Course and Scene where Degree of Danger is Changed

Table 3 Scene Information

Scene Number	Vehicle Behavior	External Situation (Dangerous Situation)	Degree Of Danger Of The Scene
(1)	Parking	-	1
	Driving	-	2
	Driving	Vehicle Approaching From Back	5
(2)	Driving	-	2
	Driving	Vehicle Approaching From Right	5
(3)	Driving	-	2
	Driving	Driving On Narrow-Road	4
(4)	Driving	Driving On Narrow-Road	4
	Driving	Driving On Narrow-Road + Parked Vehicle Detected	5
(5)	Driving	Driving On Narrow-Road	4
	Driving	Human Approaching From Right	5
	Parking	-	1

For evaluation, an evaluation vehicle runs round the course once in **Fig. 11** while operating DDC. In consideration of safety of subjects, each of the subjects is placed on the passenger seat, and one of us drove the evaluation vehicle. The subject on the passenger seat is prompted to watch a content output from output devices and to check provided information which changes in accordance with the degree of dangers of scenes. After running around the course, DDC was evaluated. The evaluation method was a subjective evaluation based on a questionnaire survey. In the questionnaire survey, two questions were adopted concerning whether DDC was felt useful and whether there was any advice or finding as to DDC. For the former, if it was felt useful, YES was selected, otherwise NO was selected. For the latter, if there is any advice or finding, leaving a comment in a separately provided comment space was prompted. The number of subjects was equal to 47.

4.2 Evaluation Result

The questionnaire results of the survey are illustrated in **Fig. 12**.

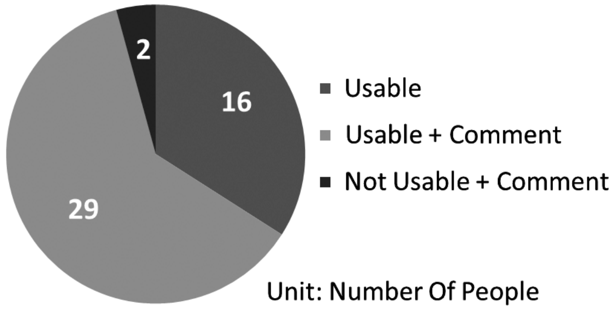


Fig.12 Questionnaire Results

As questionnaire results, 45 of 47 subjects answered that DDC was useful. Because 90% or more of the subjects answered that DDC was useful, the usefulness of DDC developed as described in this paper could be verified. 31 of 47 subjects commented advices and findings regarding DDC. **Table 4** describes results of classification and organization of comments based on details of the advices and findings.

Table 4 Advice and Findings about DDC

Advice And Findings (Roughly Categorized)	Advice And Findings (Finely Categorized)	Number Of Comments
Regarding Reduction Of Annoying Presentations	Regarding Naturally Acceptable Way Of Notification	7
	Regarding Way Of Notification Which IS Not Annoying	8
	Regarding Way Of Notification Including Driver Information	5
	Regarding Personally Adjusted Way Of Notification	6
Regarding Optimum Information Presentation	Regarding Way Of Information Presentation	11

The comments were roughly divided into comments regarding reduction of annoying presentations and comments regarding optimum information presentations. The former corresponds to advices and findings that notifications from DDC must be naturally acceptable and must not be felt unsolicited by a driver. The latter corresponds to advices and findings that easily acceptable presentation of information is necessary by figuring out some way to improve the HMI. We had recognized these two problems from before and recognized them anew from this evaluation.

We are now coping with the two problems for resolution. The problem regarding the reduction of annoying presentations may be resolved by grasping internal factors of a driver from driver information acquired by driver monitoring and understanding how the driver recognizes the notifications. The optimum information presentations may be achieved by designing the HMI based on human engineering and behavior navigation, evaluating driver's response time and receptivity to the presented information, and bringing the HMI design closer to driver's preference.

5 Conclusion

For satisfying the comfort and safety needs, we have proposed DDC for reducing DD by controlling the types and the amounts of information to be provided to a driver based on the external environment information, the host vehicle information, and the driver information, and have examined specific means for implementing it.

Also, for verification of usefulness of DDC and extraction of problems concerning DDC, the DDC system was developed, and a subjective evaluation through a questionnaire survey was performed thereon. As a result of the questionnaire survey, the usefulness of DDC was verified. The advices and findings regarding DDC could be roughly divided into comments regarding reduction of annoying presentations and comments regarding optimum information presentations, from which we could recognize that the commented problems were matched with our goals.

We will continuously cope with the problems recognized from the questionnaire survey anew and feed back remedial measures from now on. Since additional sensors for acquiring driver information are required for coping with the problems, we will start with review of sensors to be added and development of a scheme for estimation of the degree of driver's margin in addition to driver information.

The functionality for predicting a driving state is also under review as an additional function of DDC. By using the additional prediction function, information regarding incident-related-points, traffic congestions, and accidents on a driving route can be informed to a driver earlier than the current DDC. This can prompt a driver to change the route and contribute to preventive safety like avoidance of incident-related-points, and the like, which can improve the safety achieved by DDC greatly.

Reference

1) NHTSA : Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices, 2013

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