Analysis of Braking Behavior in Car Following and Its Application to Driver Assistance System

Takahiro Wada*, Shun'ichi Doi*, Akihiro Nishiyama*
Kazuyoshi Isaji, Naohiko Tsuru**, and Hiroshi Kaneko*****
*** Kagawa University, **DENSO CORPORATION, ***PARIS MIKI Inc.**

*Dept. of Intelligent Mechanical Systems, Kagawa Univ.
Takamatsu, Kagawa, 761-0396, JAPAN
Phone: (81) 87-864-2336
Fax: (81) 87-864-2369
E-mail: wada@eng.kagawa-u.ac.jp

The purpose of this paper is to analyze braking behavior of an expert driver in car following as an example of comfortable braking pattern and to apply the results to brake assistance system. Expert driver's braking behavior will be formulated using our proposed indices representing driver's perceptual risk of collision from visual input. Smooth deceleration profiles will be generated for wide range of approaching conditions. Brake initiation timing is also modeled by brake judgment line. Finally, a control method for brake assistance system will be proposed based on the formulated braking behavior. The proposed control method is installed both in a real car and a driving simulator. Experimental results will show that the proposed method generate smooth deceleration control. In addition, the experimental results show an offset of the brake judgment line can change bake initiation timing.

Topics / Braking behavior, Driver assistance system, Brake assistance system

1. INTRODUCTION

Braking assistance system is useful to avoid rear-end crashes or mitigate their damages. In order to realize an acceptable system, it is important to know characteristics of comfortable deceleration behavior. There are a lot of researches braking behavior in car following situation. Lee [1] have developed theoretical framework of drivers longitudinal control based on TTC (Time-To-Collision) associated with visual input. On the deceleration behavior, Goodrich et al. [2] characterize the behavior in a phase plane of TTC vs. THW (Time-Headway). Kondoh et al. investigate the risk perception based on TTC and THW [3]. These imply that drivers determine the timing of brake initiation and deceleration patterns based on their own perceptual risk. These researches do not deal with modeling of braking profile. On the other hands, driving models have been derived in traffic flow as following models. GHR model is a well-known car following model in traffic engineering[4]. Gipps proposed a following model that can take driver's delay time and preferred driving velocity into consideration[5]. In addition, there are some researches about evaluation of Adaptive Cruise Control(ACC) system using car-following model such as Gipps model[6]. These researches focused on the deceleration and acceleration behavior as flow in traffic environment and not on each braking behavior's characteristics. Hiraoka et al. derived car-following model for realizing comfortable ACC system applying concept of minimum jerk theory to longitudinal vehicle behavior[7].

We have proposed a performance index of approach and alienation, K_{dB} as a model of driver's perceptual risk of a preceding vehicle and its another version, K_{dB_c} based on area change of preceding vehicle on driver's retina. These indices were applied to analysis of braking behavior such as braking profile[8] and brake initiation timing[9].

In this paper, an expert driver's deceleration patterns will be formulated using the proposed index and the results will be applied to brake assistance system. First, an expert driver's braking behavior in car following situation will be measured in a test courses of an auto manufacturer. The deceleration patterns will be formulated by simple mathematical model by extracting an expert driver's braking characteristics. It will be shown that the formulated braking pattern can generate smooth deceleration profile for wide range of approaching conditions of relative velocity and brake initiation timing uniformly. In addition, brake initiation timing will be characterized using another version of the index K_{dB_c}. Equation of brake judgment line that can determine brake initiation timing will be derived with the index. Based on these characterizations of braking behavior, a control method of braking assistance system will be derived. The control method will be installed in a real car and brake initiation timing and brake profile will be evaluated by subjective rating. Furthermore, the control method will be also installed in the driving simulator to evaluate change method of brake initiation timing to adapt to individual differences.

2. DEFINITION OF PERFORMANCE INDEX OF APPROACH AND ALIENATION

Suppose that we follow a car in the same lane as shown in Fig.1. In such situation, the driver evaluates the risk against approach of the preceding car appropriately and realizes safe driving by operating pedals and steering wheel based on the perceived results. So far, we have hypothesized that drivers detect the approach of the preceding car and sense the risk by its area changes on the retina and determine the operation of deceleration based on it and the performance index of approach and alienation K_{dB} has been derived[8].

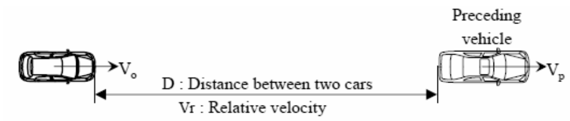

Fig. 1 Car Following Situation

Fig.2 shows a schematic image of area change of a preceding car on the driver's retina in approaching situation. The area on the retina is proportional to $1/D^2$, where D denotes the gap between two cars. Then, its time derivative can be written as follows:

$$K(Vr, D) = \frac{d}{dt}\frac{1}{D^2(t)} = -2\frac{V_r(t)}{D^3(t)} \quad (1)$$

where

$$V_r(t) = V_p(t) - V_o(t) = -\frac{d}{dt}D(t) \quad (2)$$

and V_r, V_p, and V_o denote relative velocity and the velocities of preceding car and own car, respectively. Variable K changes in wide range for example it changes in the order of 10^6 corresponding to D=1 to 100[m]. Thus, in practical manner, we introduce logarithm expression of K. Assuming the threshold to detect the approach of the preceding car at D=100[m] and V_r=-0.1[km/h] yields

$$K_0 \equiv K(-0.1, 100) = 5\times10^{-8}. \quad (3)$$

Now K_{dB} is defined as eq.(3) that is the logarithm form of K to the base 10 so that K_{dB} = 0[dB] when K=K_0.

$$K_{dB} = \begin{cases} 10\log_{10}(|K/K_0|)\mathrm{sgn}(-Vr) \\ = 10\log_{10}(|\,4\times10^7\times\frac{V_r}{D^3}|)\mathrm{sgn}(-Vr) \\ \qquad\qquad (|\,4\times10^7\times V_r/D^3|\geq 1) \\ 0 \qquad\qquad (|\,4\times10^7\times V_r/D^3|<1) \end{cases} \quad (4)$$

It has been shown that crash data and normal safe driving data can be distinguished by the index based on the micro crash data and the experimental results with real cars[8].

We call this variable K_{dB} "performance index for approach and alienation" at the moment of the driver's operation such as deceleration and acceleration. Indices K and K_{dB} are increased when the preceding car is approaching relatively to own car as similar as increase of the driver's visual input. K_{dB} is increased when the driver do not react for this regardless of cause of risky conditions such as low arousal level, inattention or other reasons depending on driver's status. It has been shown that K_{dB} can discriminate between braking behaviors of normal safe driving and those in crash accidents that are extracted from micro data of crashes[8].

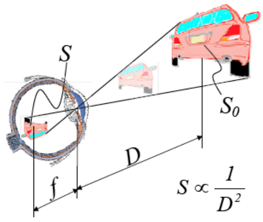

Fig. 2 Visual Input on Retina

3. INVESTIGATION OF EXPERT DRIVER'S DECELERATION BEHAVIOR

3.1 Experimental conditions

In order to formulate expert driver's smooth deceleration behavior in normal driving, braking experiments with a test driver of an auto manufacturer were conducted in a test course.

A preceding car runs at constant velocity Vp and the following car driven by the test driver approaches at constant velocity Vo. The subject was instructed not to decelerate as long as he feels that the collision was avoidable with his normal decelerate behavior and to decelerate at his limit of normal braking operation. Three experimental conditions are utilized as the combinations of Vp and Vo.

3.2 Experimental results

As shown in Fig.3, it is found that the driver decelerates to maintain the slope dK_{dB}/dD at the brake initiation timing for all conditions and then peak deceleration is kept until V_r=0 is realized. Interestingly, K_{dB} patterns are almost linear even though deceleration, V_r and TTC patterns are nonlinear. Dotted lines in the figures illustrate simulation results using the feature that the braking behavior completely satisfies $dK_{dB}(t)/dD$= $dK_{dB}(t_{bi})/dD$ where t_{bi} denotes time at brake initiation and peak of the deceleration is held given the same brake initiation timing as the experimental results. In the simulation, V_p, V_o at the initial status and TTC at brake initiation are extracted from the experimental results and used in the simulation. The experimental results and the simulation results coincide well. Similar behavior can be seen with the condition of (V_p=40, V_o=100[km/h], TTC=4.75[s]) and (V_p=23, V_o=40[km/h], TTC=4[s]) (no figure). It should be noted that same tendency can be found in braking behavior of general drivers[8].

4. FORMULATION OF EXPERT DRIVER'S BRAKE PROFILE

4.1 Deceleration profile modeling

Fig.4 is a schematic image of expert driver's deceleration model that we found in section 3, that is, index K_{dB} is changed with the same slope

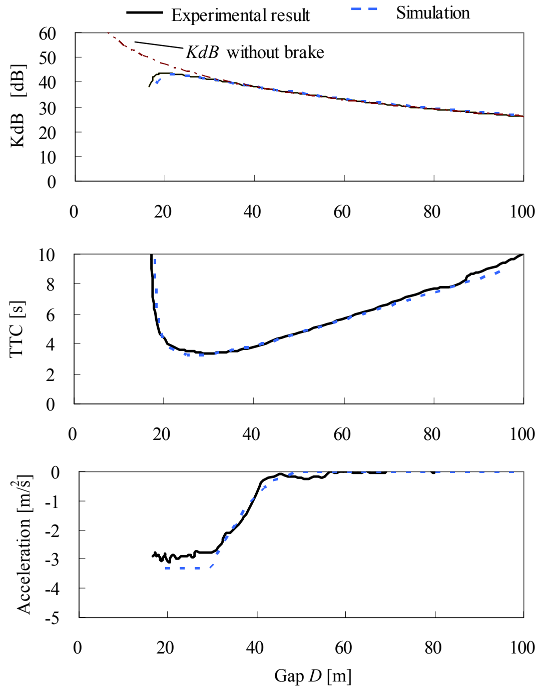

Fig. 3 Test Driver's Deceleration Behavior and Simulation Results V_p=40, V_0=80[km/h], TTC=4.5[s].

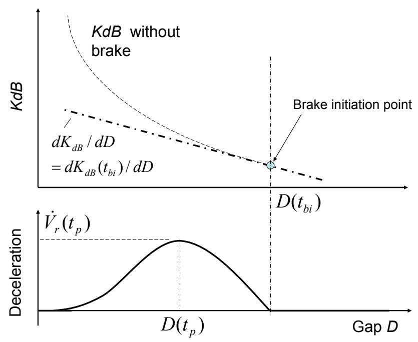

Fig.4 Schematic Image of Expert Driver's Deceleration Profile

$dK_{dB}/dD=dK_{dB}(t_{bi})/dD$. We formulate the above properties in the followings.

We deal with only approaching situation to a preceding car in the remaining part of the paper for the sake of simplicity. Here K_{dB} can be rewritten as follows with this condition and assumption of $|4\times10^7\times V_r/D^3|\geq1$:

$$K_{dB} = 10\log_{10}(4\times10^7\times\frac{-V_r}{D^3}) \tag{5}$$

Differentiating eq.(5) by gap D yields

$$\frac{dK_{dB}(t)}{dD(t)}=\frac{10}{\ln 10}\left(\frac{\dot{V}_r(t)}{V_r^2(t)}-\frac{3}{D(t)}\right). \tag{6}$$

Then constant slope feature can be written as (7).

$$\frac{dK_{dB}(t)}{dD}=\frac{dK_{dB}(t_{bi})}{dD} \tag{7}$$

Substituting eq.(6) into eq.(7) yields

$$\frac{\dot{V}r(t)}{Vr^2(t)}-\frac{3}{D(t)}=\frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}-\frac{3}{D(t_{bi})} \tag{8}$$

Solving eq.(8) by relative acceleration leads to deceleration profile model (9).

$$\dot{V}r(t)=\left(\frac{3}{D(t)}-\frac{3}{D(t_{bi})}+\frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}\right)Vr^2(t) \tag{9}$$

With constant feature, definition of K_{dB} and eq.(7) leads to eq.(10).

$$\begin{aligned}K_{dB}(t)&=10\log_{10}\left(4\times10^{-7}\frac{-V_r(t)}{D^3(t)}\right)\\&=\frac{10}{\ln 10}\left(\frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}-\frac{3}{D(t_{bi})}\right)(D(t)-D(t_{bi}))\\&\quad+10\log_{10}\left(4\times10^{-7}\frac{-V_r(t_{bi})}{D^3(t_{bi})}\right)\end{aligned} \tag{10}$$

Solving (10) by V_r(t) yields profile of relative velocity as (11).

$$Vr(t)=\frac{Vr(t_{bi})}{D^3(t_{bi})}D^3(t)\exp\left\{\left(\frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}-\frac{3}{D(t_{bi})}\right)(D(t)-D(t_{bi}))\right\} \tag{11}$$

<u>Constant relative velocity situation</u>

For the sake of simplicity, we deal with situations of approaching to a preceding car running at a constant velocity. In this situation, relative deceleration is zero until braking behavior of the following car's driver. Based on this assumption, substituting $\dot{v}_r(t_{bi})=0$ into eqs.(9), (11) leads to eqs.(12) and (13), respectively.

$$\dot{V}r(t)=\left(\frac{3}{D(t)}-\frac{3}{D(t_{bi})}\right)Vr^2(t) \tag{12}$$

$$Vr(t)=V_r(t_{bi})d^3(t)\exp\{3(1-d(t))\} \tag{13}$$

where $d(t) = D(t)/D(t_{bi})$. From eq.(12), dot Vr reaches at zero when Vr=0 otherwise dot Vr always takes positive value, say, deceleration. In addition, from eq.(13), V_r reaches at zero when D goes to zero otherwise V_r always takes negative value because $v_r(t_{bi}) < 0$ is assumed. From these results, the derived deceleration profile guarantees no collision under the given assumptions as long as the calculated deceleration can be generated but the state is uniquely converged to its equilibrium point $[V_r, D]^T = [0, 0]^T$.

Fig.5 illustrates calculated results of eq.(12) with $V_r(t_{bi})$=-20Km/h without relative deceleration until brake initiation. Two lines in each graph show $D(t_{bi})$=25m and 50m. Very smooth deceleration profile can be obtained with only simple calculation of eq.(12).

As the results, our model can generate very smooth and safe(collision-less) deceleration profile with simple calculation but without any complex calculation such as solving optimal problem.

4.2 Relationship between peak acceleration and gap at brake initiation

Peak relative acceleration can be obtained by substituting zero into time derivative of relative acceleration of eq.(9) as eq.(14).

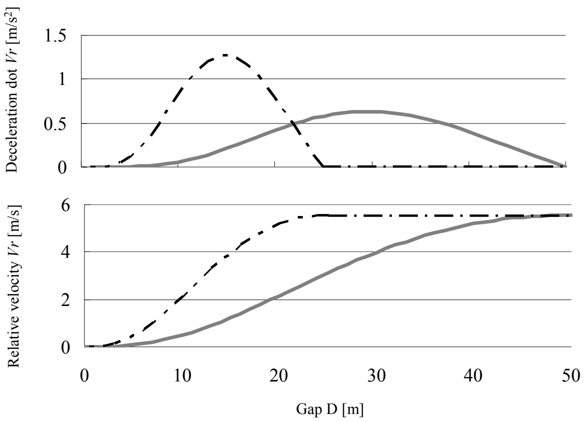

Fig.5 Calculated Deceleration and Velocity Profile

$$\dot{V}r(t_p) = \frac{3}{2}\frac{Vr^2(t_p)}{\left(\frac{3}{D(t_p)} - \frac{3}{D(t_{bi})} + \frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}\right)D^2(t_p)} \qquad (14)$$

where t_p denotes timing of peak relative acceleration. Substituting (11) into (14) and solving it by gap D lead to the gap with the peak of relative acceleration eq.(15).

$$D(t_p) = \frac{3-\sqrt{6}/2}{\frac{3}{D(t_{bi})} + \frac{\dot{V}r(t_{bi})}{Vr^2(t_{bi})}} \qquad (15)$$

It shows that the gap with the peak relative acceleration can be obtained uniquely by determining relative acceleration, relative velocity, and the gap at brake initiation timing.

For the sake of simplicity, we deal with situations of approaching to a preceding car running at a constant velocity. Based on this assumption, substituting $\dot{v}_r(t_{bi}) = 0$ and eq.(15) into eq.(14) leads to (16).

$$\dot{V}r(t_p) = \frac{\sqrt{6}}{2}\left(1-\frac{\sqrt{6}}{6}\right)^5 \exp(\sqrt{6})\frac{Vr^2(t_{bi})}{D(t_{bi})} \qquad (16)$$

Solving eq.(16) by $D(t_{bi})$ leads to eq.(17).

$$D(t_{bi}) = \frac{\sqrt{6}}{2}\left(1-\frac{\sqrt{6}}{6}\right)^5 \exp(\sqrt{6})\frac{V_r^2(t_{bi})}{\dot{V}_r(t_p)} \approx 1.03\frac{V_r^2(t_{bi})}{\dot{V}_r(t_p)} \qquad (17)$$

Fig.6 shows examples of maximum relative acceleration vs the gap D at brake initiation calculated by (17). Eq.(17) shows that if $Vr(t_{bi})$ is given, brake initiation timing can be determined from peak deceleration. Namely, the gap when brake initiation is inversely proportional to the peak acceleration. This implies that drivers can estimate brake initiation timing from the current relative velocity and estimated or preferable maximum deceleration based on environmental condition such as road conditions etc. Thus, our driver deceleration model seems to reflect human drivers' simple control scheme.

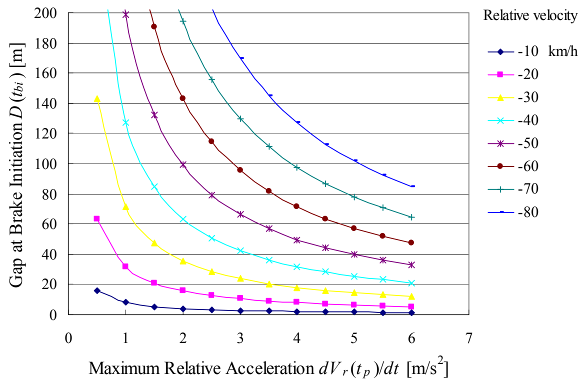

Fig. 6 Max. Relative Acceleration vs Brake Initiation

5. ANALYSIS OF BRAKE INITIATION TIMING

By looking at relationship between K_{dB} at brake initiation and D of the experimental results in Section 3, smaller K_{dB} is recorded at higher speed of the preceding vehicle V_p. This implies that at the situation with large V_p, drivers tended to drive more safely. So, to take this phenomenon into account, we modify K_{dB} by adding a term relating to V_p. For this purpose, K_{dB_c} is introduced as follows[9]:

$$K_{dB\_c}(a) = \begin{cases} 10\log_{10}\left(\left|4\times10^7 \times \frac{-V_r + aV_p}{D^3}\right|\right)\mathrm{sgn}(-V_r + aV_p) & (|4\times10^7 \times (-V_r + aV_p)/D^3| \geq 1) \\ 0 & (|4\times10^7 \times (-V_r + aV_p)/D^3| < 1) \end{cases} \qquad (18)$$

Namely, the term of $-V_r$ of K_{dB} is replaced by $-V_r + a V_p$. Let us assume that $K_{dB\_c}(a)$ at brake-initiation timing is approximated in $K_{dB\_c}(a)$ vs D plane by the following equations:

$$K_{dB\_c}(a) - b\log_{10} D - c = 0 \qquad (19)$$

The coefficient a is determined so that the approximated error of the equation is minimized in terms of least squares. For the test driver, a=0.3 is obtained and the judgment line of brake initiation timing is obtained as follows[9]:

$$K_{dB\_c}(0.3) + 23.76\log_{10} D - 76.96 = 0 \qquad (20)$$

Eq.(20) fits well to the real brake initiation timing as shown in Fig.7.

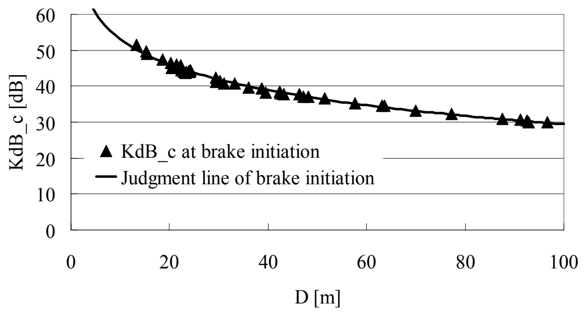

Fig.7 K_{dB_c} at Brake Initiation and Judgment Line

It has already been shown that the judgment line of brake initiation can discriminate between normal safe driving and micro data of crashes very well[8]. Probability that the plots for the normal driving are located in the upper area than the line is 0.00694. On the other hand, for the crash data, probability that the crash data is located lower than the line is 0.

6. APPLICATION OF DECELERATION MODEL TO BRAKE ASSISTANCE SYSTEM

6.1 Brake Control Method

To realize comfortable braking control, the braking behavior model is applied to its control method. Namely, brake initiation timing can be determined by judgment line of brake initiation. In order to adapt individual differences, offset of the line Δc is added to eq.(19) as follows:

$$K_{dB\_c}(a) - b\log_{10} D - c - \Delta c = 0 \qquad (21)$$

In addition, desired velocity at any gap D can be determined by eq.(13). But, safer profile is needed because the profile realize V_r=0 at D=0. Thus, desired velocity profile $V_r^d(t)$ is determined by adding offset in the gap D to the velocity profile so that V_r=V_r_offset>0 is realized at D=0 as follows:

$$\begin{aligned} V_r^{\,d}(D) &= \frac{V_r(t_{bi})}{D^3(t_{bi})} D^3(t)\exp\left\{-\frac{3}{D(t_{bi})}(D(t)-D(t_{bi}))\right\} \\ &\quad + Vr\_offset\frac{D(t_{bi})-D(t)}{D(t_{bi})} \\ &= V_r(t_{bi})d^3(t)\exp\{3(1-d(t))\} + Vr\_offset(1-d(t)) \end{aligned} \qquad (22)$$

With this offset, Vr=0 is realized with the gap D>0, say, no collision. Then, let consider how to construct acceleration command from these velocity profile. Here, the deceleration command is determined by the following simple method:

$$G = -k_p(V_r^{\,d}(D) - V_r(t)), \qquad (23)$$

where k_p is feedback gain.

Consequently, the following control method has been obtained:

1) K_{dB_c} is calculated in real-time from measured $V_r(t)$, $D(t)$ and $V_p(t)$ or $V_o(t)$.
2) Brake control starts when K_{dB_c} exceeds the judgment line of brake initiation eq.(21).
3) Desired deceleration can be determined by the deceleration profile model eq.(23).

6.2 Evaluation of the brake assistance method with a real car

The proposed control method is installed to a real car and subjective evaluation by drivers in an auto manufacturer is performed in a test course. Twenty five skilled drivers (mean age 54.2yrs) who did not concern this research participated in the experiments.

(a) Evaluation of brake initiation timing

Participants are asked to comment on the braking timing of the brake assistance system in free style, then the experimenters classify into three categories of earlier than his/her own timing, almost same, and later. In this experiment, Δc=1dB is employed to avoid excessive dependency on the system. There are two conditions of constant relative velocity with Vp=60km/h and Vo=100km/h and sudden deceleration with dVr/dt=1m/s^2 from Vo=Vp=60km/h with initial distance D0 (mean:19.4m, SD:3.7m).

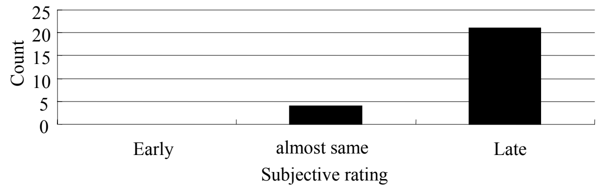

Fig.8 Subjective Evaluation on Brake Initiation Timing

Twenty one participants rated as later than their own braking as shown in Fig.8. This means that the brake initiation timing with Δc=1dB does not result in excessive dependency. But the fact that four participants rated almost same as their own timing implies that a method to adapt such individual differences are required.

(b) Evaluation of smoothness of deceleration profile

The participants are asked to comment on smoothness and security of the deceleration profile in free style, then the experimenters classify into three categories of poor than his/her own braking, good as their own braking and very good. In this experiment, Δc=-3dB is employed to collect detailed comments with safer conditions. The same two conditions as the previous experiments are experienced by the participants.

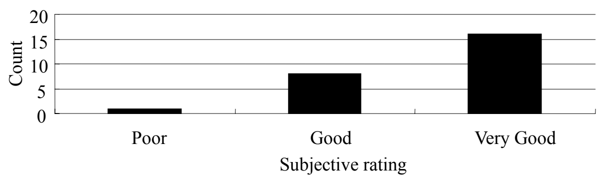

Fig.9 Subjective Evaluation on Brake Profile

Almost all participants rated as good as their own or very good except for one participant as shown in Fig.9. There are many comments that the control method realizes very smooth deceleration, especially in the start and end of the braking.

6.3 Evaluation of adaptability to individual differences

In order to see feasibility of adaptation to individual difference, the effect of the offset of brake judgment line on subject rating is investigated using driving simulator. The same control method as the previous section is installed in our fixed based driving simulator. There are three conditions in the offset Δc=0, +-0.5dB.

Participants take driving posture and step on the throttle and follow a leading vehicle while no operation reflects on the vehicle behavior. Then the participants observe the automatic deceleration and evaluate the deceleration timing subjectively in 5 levels of late, late slightly, appropriate, early slightly, early by comparing with their own brake initiation timing. On the other hand, the participants drive the driving simulator by themselves and braking behavior is measured. There are two conditions in velocities as (Vo=80km/h, Vp=40) and (Vo=80, Vp=20). The participants are eight young male students.

Fig.10 shows an example of the effect of brake initiation timing of brake assistance system on subjective evaluation. It is found that automatic deceleration is evaluated as appropriate or early slightly with the brake initiation by the judgment line (Δc=0). This means the brake initiation timing of the judgment line works well for automatic braking. In addition, by adding offset of +0.5dB and -0.5dB, subject ratings are uniformly changed. This implies that adjustment of brake initiation timing such as individual differences can be absorbed by just adding the offset Δc.

Fig.11 shows that brake initiation timing of the same subject for all trials. Scattering of brake initiation timing can be inside of offset of Δc=+-0.5dB with the brake judgment line. This implies that the subject ratings in Fig.10 are adequate.

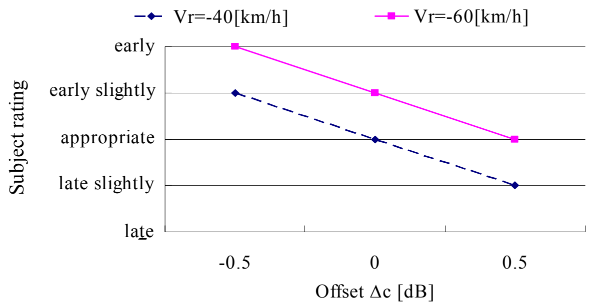

Fig.10 Effect of Offset of Brake Line on Subject Rating

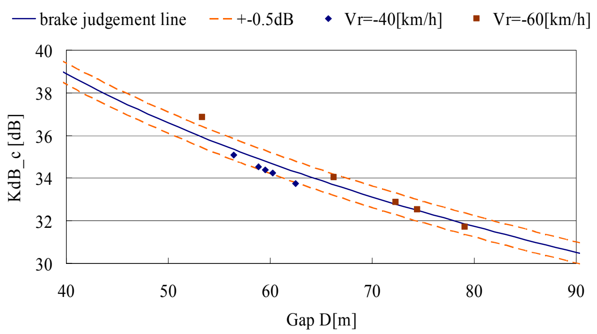

Fig.11 Brake Initiation Timing of Subject

7. CONCLUSION

Braking behavior in car following situation is analyzed using our proposed indices K_{dB} and K_{dB_c} that reflect driver risk cognition characteristics of approaching car. Braking profile of an expert driver was formulated and it is found that the formulated deceleration profile can generate very smooth velocity and deceleration profile for wide range of approach situations without any complex calculation. In addition, brake initiation timing was modeled as a brake initiation line with very high accuracy. Based on these models, a new control method of brake assistance system was proposed. The method was installed into the real car and the driving simulator. Subject ratings show that the method generates very comfortable deceleration profile. Further offset method of brake timing succeeded to change subject rating uniformly.

As the future study, robustness of the method will be investigated including high emergency situation or complex traffic environment. In addition, influence of the system on the traffic flow will be investigated because the brake assistance system affects driving behavior of following traffics even though it seems that negative effect is very small because our proposed method generates very smooth and human-like deceleration profile. Furthermore, the method will be applied to other wide range of traffic environment such as curve deceleration control etc.

REFERENCES

[1] Lee, D.N., “A Theory of Visual Control of Braking Based on Information about Time-To-Collision”, Perception, Vol.5, 1976, pp.437-459.

[2] Goodrich, M.A., Boer, E.R., Inoue, H.A., “Characterization of Dynamic Human Braking Behavior with Implications for ACC Design”, Proc. IEEE Conference on Intelligent Transportation Systems, 1999, pp.964-969.

[3] Kondoh, T. Yamamura, T. Kitazaki, S. Kuge, N. and Boer, E.R., “Identification of Visual Cues and Quantification of Drivers’ Perception of Proximity Risk to the Lead Vehicle in Car-Following Situations”, Proceedings of Driving Simulation Conference Asia/Pacific, 2006, CD-ROM.

[4] Gazis, D. C., Herman, R., and Rothery, R. W., “Nonlinear Follow-the-leader Models of Traffic Flow”, Operations Research, vol.9, no.4, 1961, pp.545-567.

[5] Gipps, P. G., “A Behavioral Car-following Model for Computer Simulation”, Transportation Research Board, vol.15B, 1981, pp.105-111.

[6] Bareket, Z., Fancher, P. S., Peng, H., Lee, K., and Assaf, C. A., “Methodology for Assessing Adaptive Cruise Control”, IEEE Transactions on Intelligent Transportation Systems, vol.4, no.3, 2003, pp.123-131.

[7] Hiraoka, T., Kunimatsu, T., Nishihara, O., and Kumamoto, H., “Modeling of Driver Following Behavior based on Minimum-jerk Theory”, Proceedings. of 12th World Congress on Intelligent

Transport Systems, 2005, CD-ROM.
[8] Wada, T., Doi, S., Imai, K., Tsuru, N., Isaji, K., and Kaneko, H., "Analysis of Drivers' Behaviors in Car Following Based on A Performance Index for Approach and Alienation", SAE 2007 Transactions, Journal of Passenger Cars – Mechanical Systems, SAE paper 2007-01-0440, 2008 (in press).
[9] Wada, T., Doi, S., Imai, K., Tsuru, N., Isaji, K., and Kaneko, H., "Analysis of Braking Behaviors in Car Following Based on A Performance Index for Approach and Alienation", Proceedings of IEEE Intelligent Vehicles Symposium, 2007, pp.547-552.

Published in: 9th International Symposium on Advanced Vehicle Control, AVEC '08
(Proceedings, Avec '08-097 No.20080497)
Date of Conference: Oct.2008
Publisher: Society of Automotive Engineers of Japan
Publication Year: 2008