Application of Visibility Index Function for Driving

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ABSTRACT

We demonstrate that a VIF (Visibility Index Function) can be applied for precisely simulating and improving the visibility of driving environments as well as human-interface devices in a driving task. The VIF is convenient to design information display and traffic signs by considering visibility while driving.

1 INTRODUCTION

While driving a vehicle, drivers must pay attention to many things quickly and properly. For example, to keep the distance from the car in front and to turn the steering wheel smoothly, they must essentially continue seeing the front. In addition, drivers sometimes must look toward the displays and check the traffic signs. Therefore, the positions of visual devices in the car interior and the contents displayed are critical for driving safety. However, it remains unclear how we can predict the visibility of characters using physical parameters, such as the character size, the luminance values of the character and the background. Here, we introduce a visibility index function for characters and propose an application for a driving task.

2 VIF (Visibility Index Function)

Previously, we defined a visibility index function (VIF) of text as

$$\mathbf{VIF}(A, L_b, \Delta L) = 5.5\frac{\log(\Delta L+1)}{\log(L_b+4)} + 5.5\log(A) - 8.7 \quad \textbf{(1)},$$

where A (min) is the visual angle of character's height, L_b (cd/m^2) is the background luminance and ΔL (cd/m^2) is the difference between character and background luminances[1] (Fig.1). In general, it has been thought that contrast $C = \Delta L / L_b$ is an important parameter for determining the visibility. However, Eq.(1) shows that ΔL and L_b independently contribute to the visibility through nonlinear logarithm functions. The value of VIF represents an index with six ranks ranging from 0.5 to 5.5 and these rank-categories were: 0.5 "Not at all readable", 1.5 "Very difficult to read", 2.5 "Moderately difficult to read", 3.5 "Normally readable", 4.5 "Moderately easy to read", 5.5 "Very easy to read". VIF can precisely predict the visibility of positive contrast text.

Conversely, the character size A which guarantees a visibility index can be calculated by this formula. Originally, VIF was derived from the experimental data with printed texts but it was confirmed that is precisely applicable for texts on a visual display terminal without any change of the coefficients [2] (Fig.2).

Fig. 1 Parameters of the VIF in Eq.(1)

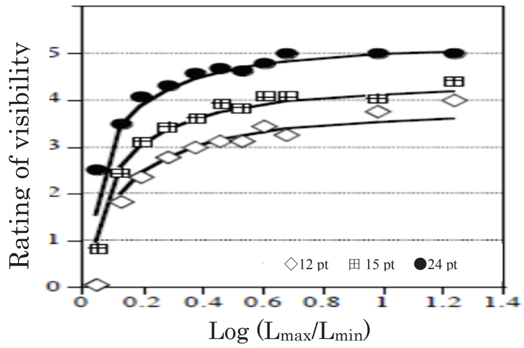


Fig. 2 Experimental data (symbols) and predicted values by VIF (solid lines) of visibility rating using an LC-display

Moreover, we measured visibility of several chromatic texts presented on a chromatic background with an LC-display quantitatively and extended the VIF so as to explain the experimental results with a higher degree of accuracy3). In addition to character luminance, background luminance and character size, we provided several saturation and hue conditions on chromatic text to analyze the effect of colors of text and background in the experiment. We replaced ΔL to $\Delta L'$ and L_b to L_b' as follows:

$$\Delta L' = \sqrt{\Delta L^2 + (0.321\Delta u * v *)^2} \quad (3),$$

$$L_b' = \sqrt{L_b{}^2 + (0.0015 C_b * A^2)^2} \quad (4),$$

where Δu^*v^* is the color difference using the chromatic indices in CIELAB and C_b is the background saturation using the chromatic indices, respectively. The results show that the original VIF cannot well predict the experimental data in small luminance difference conditions and large character size condition. We formulated the effects of colors and indicated that our improved VIF ca precisely estimate actual visibility of chromatic texts presented on a chromatic background.

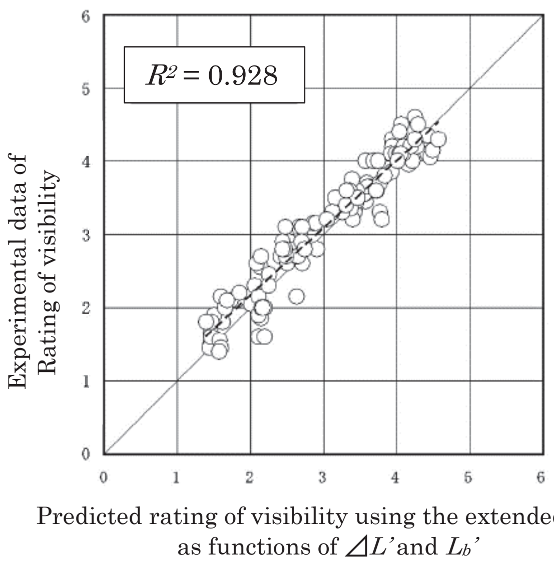


Fig. 3 Correlation between experimental data (vertical axis) and predicted values by the extended VIF (horizontal axis) of visibility rating of colored characters

3 APPLICATION FOR VISIBILITY SIMULATION

Suppose, for instance, there is a traffic sign. We can derive the visibility R from Eq.(1) as

$$R(L_b, \Delta L, \alpha, D) = 5.5\frac{\log(\Delta L + 1)}{\log(L_b + 4)} + 5.5 log\left\{\frac{360}{\pi} tan^{-1}(\frac{\alpha}{2D})\right\} - 8.7 \quad \textbf{(2)},$$

where α is the height of characters in meter and D is the visual distance in meter shown in Fig.4.

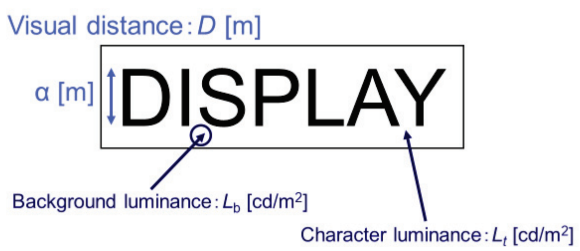


Fig. 4 Parameters of Eq. (2)

Then we can simulate the visibility change as a function of visual distance D as Fig. 5. Figure 6 is the result of the simulation, indicating that 100 [m] is a critical distance as a border of "Normally readable" and "Moderately difficult to read" when the background luminance L_b = 30 [cd/m^2], the character luminance L_t = 130 [cd/m^2] and the character height α =0.5 [m]. This is very useful to design traffic signs, such as character size and luminance values of text and background. VIF can be applied to design instrument panels as well.

In addition, Fig.7 shows that VIF can be applied to design instrument panels. In this case, if you want to ensure a visibility of "Very easy to read (R = 5.5)" at D=1.0 [m], then a character size α [mm] derived by this formula is necessary. In this manner, VIF is convenient to design information display with considering visibility quantitatively.

The original VIF (Eq.(1)) is for young observers but we found that we can modify the VIF for the elderly by adjusting only the contribution of the character size. Also, we can apply Eqs.(3) and (4) for colored characters and/or colored background to predict the visibility more precisely. Moreover, we quantitatively analyzed the effect of an inhomogeneous luminance, which was produced by the graphical representation of a background without reflected light and by reflected light on a homogeneous background and applied a weighted average background luminance with a two-dimensional Gaussian function, whose distribution width was related to the text size, to VIF[4].

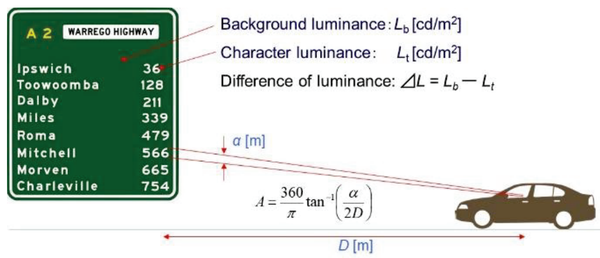


Fig. 5 The condition of a traffic sign while driving

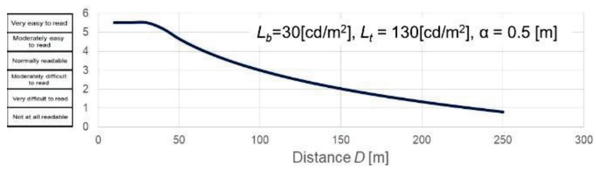
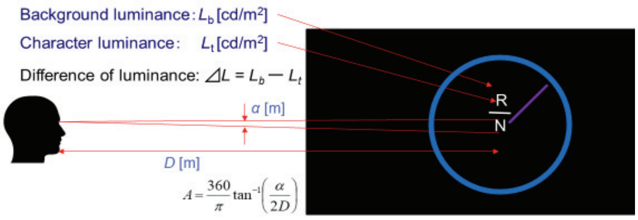


Fig. 6 The visibility of the traffic sign of Fig. 5 as a function of *D*



$$R = 5.5\frac{\log(\Delta L + 1)}{\log(L_b + 4)} + 5.5logA - 8.7$$

$$logA = \frac{1}{5.5}\left\{R - 5.5\frac{\log(\Delta L + 1)}{\log(L_b + 4)} + 8.7\right\}$$

$$A = 10^{\frac{1}{5.5}\left\{R - 5.5\frac{\log(\Delta L+1)}{\log(L_b+4)} + 8.7\right\}} = \frac{360}{\pi} tan^{-1}(\frac{\alpha}{2D})$$

$$\therefore\ \alpha \geq 2000\, tan\, (3.3 \cdot 10^{\left\{-\frac{\log(\Delta L+1)}{\log(L_b+4)}\right\}})\ \text{[mm]}$$

How to use VIF for designing information display in car

When L_b and L_t are fixed, if you want to ensure a visibility of "Very easy to read (R = 5.5)" at D=1.0 [m], the character size α [mm] is necessary.

Fig. 7 The method to determine the character size of information display

4 CONCLUSION

We can quantitively calculate and predict the visibility as functions of the character size, the background luminance and the character luminance. The VIF is quite useful to design information display and traffic signs when considering visibility while driving.

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