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THE VISIBILITY STUDIES OF DYNAMIC ROAD-LIGHTING ON A FOGGY ROAD

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Abstract

The studies on visibility of traffic sign, yellow raincoat and yellow helmet on an experimental road for dynamic road-lighting in a foggy environment were performed. We used an image luminance measuring device to measure the luminance images. The analysis of the experimental results were obtained by the defined contrast ratio and the threshold of fog index. The visibility of objects in HPS and LED lighting in the foggy environment can be analysed.

Keywords: Traffic sign, Fog, Contrast Ratio, Dynamic road-lighting

1 Introduction

Recently, there are many projects that have been proposed and be planned to build “Smart Lighting and City” for governments around the world. Dynamic road-lighting is developed for Smart City for energy saving and intelligent purposes. The most important thing is how to realize and the dimming control of dynamic lighting and to benefit the power-consumption and safety for users. There are many issues about dynamic road-lighting that have to be studied, such as visibility and dimming level, the environmental conditions for setting the dimming level and frequency of dimming control. To systematically study the issues, we used an Image Luminance Measuring Device (ILMD) to capture the luminance images of a commercial traffic sign, humanoid dummy waring a raincoat under various controllable conditions on an experimental road (Hsu, 2012). We analysed the luminance images with contrast ratio on the regions of interest (ROIs) of different objects. Therefore, the dimming control algorithms can be applied for adjusting light intensity according to traffic flow and weather information.

2 Experiments

A traffic sign with flashing LED function, humanoid dummy wearing a yellow raincoat, humanoid dummy wearing a blue raincoat and yellow helmet were placed at roadside of an experimental 2-lane road, which was lighted with LED with dimmable controller or high pressure sodium (HPS) luminaires. The road lighting experiment field was established in the southern campus of ITRI in Tainan city and shown in Fig. 1.

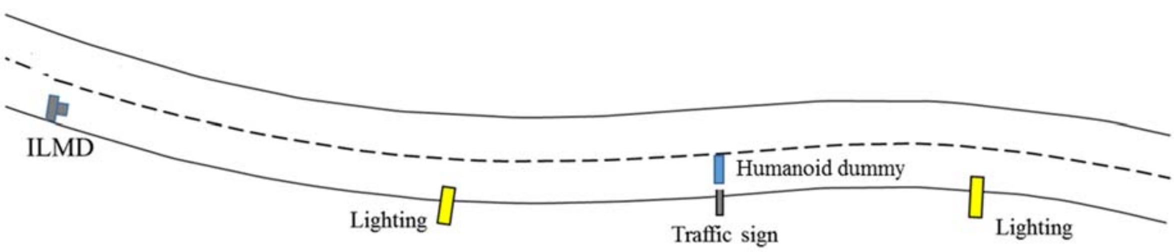
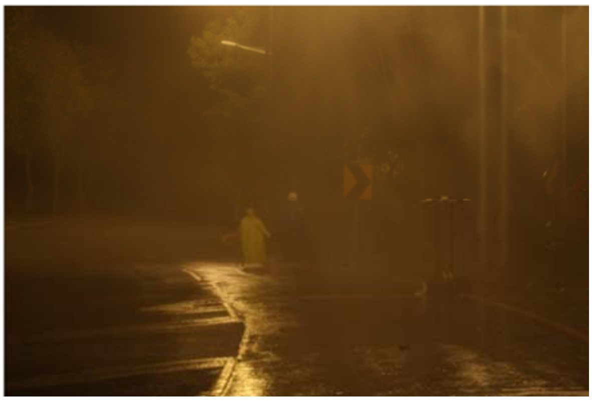


Figure 1 – Schematic top view of the experimental road.

Figure 2 demonstrates the typical experiment road and foggy condition. There are 11 dimming levels of LED street lighting which is using Bluetooth communication. The man-made fog was generated by the high pressure spread head. The flow of the spread head is 0.26 l/min. The total amount of spread heads are 650 units. Various levels of fog were generated by several water mist machines along the road. We can generate the fog between the two street lights. The distance between these two street lights is 43.8 m. Therefore we can change the lamp of street lights, dimming levels of LED and set traffic sign and objects in the foggy area.

(a)



(b)

Figure 2 – (a) Typical image of the experimental road of; (b) The foggy condition.

The ILMD can be used to measure the luminance distribution of the traffic sign and objects in foggy conditions or not. Under these experimental conditions, many of luminance images of the road were captured for the analyzations of visibility. We use Michelson contrast (*C*) ratio to analyse the visibility of traffic signs in different conditions. The visibility of traffic signs is defined between the sign area, paint area, and surrounding background. The visibility of objects are defined between ROIs of objects and surround background. These luminance images were measured with a calibrated ILMD with a 10-22 mm focal length. The ILMD was placed at distance of 30 m from the nearest pole, and the height of the ILMD is 1.5 m (CIE 194).

3 Results and Discussions

The contrast ratio of (Region of Interest, ROIs) of the objects and traffic signs to the surround background (C_{AB}) was defined as an index of influence of fog (Hsu, 2017). The contrast ratio C_{AB} can be regarded as an index of ordinary visibility in a foggy environment. The smaller C_{AB} means a more concentrated foggy environment (Hsu, 2018). The luminance of ROIs are relative to the absorbance of fog and the distance between observer and targets. Therefore, the visibility as the function of the sky luminance, the scattering of the lighting, extinction coefficient (Seinfeld, 1998) (CIE 19-2).

$$C_{\mathrm{AB}} = (L_{\mathrm{A}} - L_{\mathrm{B}})/(L_{\mathrm{A}} + L_{\mathrm{B}}) \tag{1}$$

where

L_{A} is the average luminance of ROI;

L_{B} is the background luminance.

$$L_{\mathrm{A}} = (L_{\mathrm{A0}} - L_{\mathrm{f}})e^{-f_{\mathrm{kd}}} + L_{\mathrm{f}} \tag{2}$$

where

L_{A0} is the luminance of f_{kd} approximate to 0;

L_f is the sky luminance which is clear environment;

f_{kd} is the extinction coefficient.

Figure 3 – The ROIs of humanoid dummy and traffic sign.

For the case of dimmable LED street lighting, we can compare traffic signs and objects in different dimming conditions and in the different foggy conditions which shown in Fig. 4. By analysing ROIs of the luminance images in foggy conditions, the contrast ratios dependent on the concentrations of fog and the lighting levels that can be obtained.

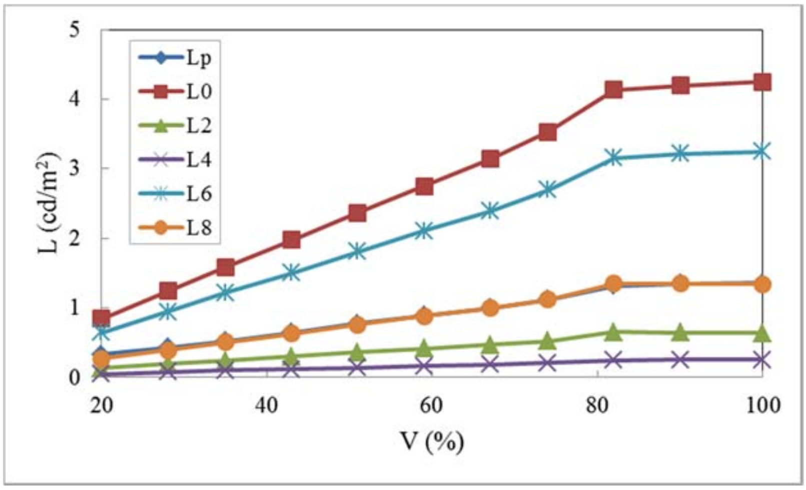


Figure 4 – The average luminance of ROIs in different dimming conditions of LED.

Also, comparing these objects and traffic signs, we can characterize the physical properties for lighting levels and concentrations of fog. Therefore, we can set the visibility threshold for the lighting level in particular foggy environments. Comparing the yellow helmet and traffic sign, in the same foggy condition, the visibility of the yellow helmet is 2.5 times greater than the traffic sign.

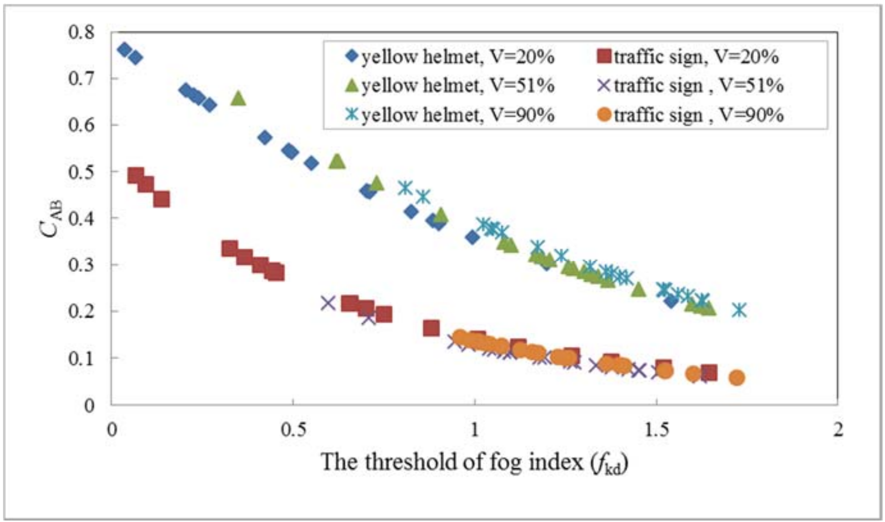


Figure 5 –The result of the threshold of fog in different dimming conditions of LED.

On the other hand, in the foggy environment, the C_{AB} and dimming level have poor correlation. The luminance of ROIs are increased in the higher level of lighting. Therefore, the higher lighting level is needed in higher concentration of fog. As the result shows that the threshold of contrast ratio and luminance of ROIs are setting as 0.1 and 1 cd/m^2, respectively. The threshold of fog index is 1, the lighting level set as 51 %, then the visibility is satisfied. Otherwise, the fog index is 1.5, the higher lighting level can't improve the visibility when the contrast ratio is below 0.1.

For the case of HPS street lighting, the threshold of fog index for yellow helmet, yellow raincoat and traffic sign are 1.71, 1.56 and 1.20, respectively.

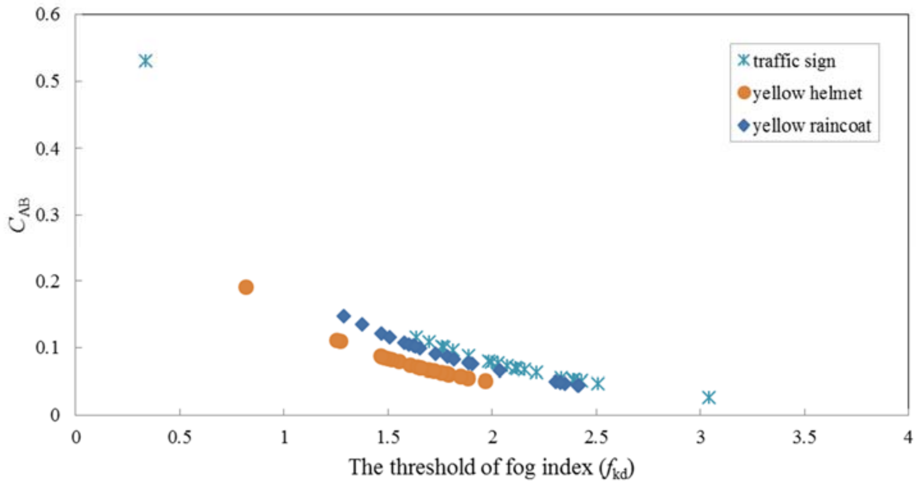


Figure 6 – The result of the threshold of fog for HPS lighting.

Compared to the LED street lighting at 100 % level, the yellow helmet and yellow raincoat in the LED street lighting have better visibility than HPS in a foggy environment. For the traffic sign, the HPS have better visibility than LED in foggy environment.

4 Conclusions

We can use ILMD to study the visibility of an experimental dimmable LED or HPS lit road in man-made foggy environment. We defined contrast ratios to analyse the visibility for various dimming conditions in a foggy environment. The experimental results show that the comparison of visibility between LED and HPS. These analysis processes as well as experimental data are expected to provide a contribution for the improvement of dynamic road-lighting.

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