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Full Length Research Paper

Analysis of visibility level in road lighting using image processing techniques

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In this study, visibility of objects on the road is tested using image processing techniques over the photo of an illuminated road. Visibility level standard of the international commission on illumination was used was for this test. Through software developed for this purpose, a correlation was established between the qualitative values of pixels and photometric units over the road photo using image processing techniques. Thanks to the correlation found, it has become possible to calculate glare values of the road and the critical object over the road. Moreover, required parameters for the visibility level are entered into the developed software, making it possible to calculate the visibility of the critical object over the road.

Key words: Road lighting, luminance, visibility level, image processing.

INTRODUCTION

The role of external lighting can be subdivided in three main purposes; to allow drivers of any kind of vehicles to proceed safely, to allow pedestrians to see hazards and to recognize the environment and other pedestrians around them, improving their sense of security; to improve the night-time appearance of the environment (Fiorentin and Scroccaro, 2009).

It is known that lighting designs depend upon both average luminance level and luminance uniformity which cause excessive lighting in some cases. It is also accepted that visual conditions might be inadequate even at luminance levels higher than the recommended values based on luminance concept for night-time road lighting conditions (Guler and Onaygil, 2003a). Therefore, a different criterion is needed to provide efficient and safe road lighting conditions. In recent recommendations on road lighting, the visibility factor has been proposed as a criterion (ANSI/IESNA RP-8, 2000; CIE, 1995).

For calculating the visibility level, initially a critical object must be chosen. The critical size corresponds roughly to the least clearance between the road surface and the body structures of normal cars. The object size was selected as 20 × 20 cm, which is the minimum size of an object which may pose a danger to a normal size vehicle. The reflection factor of the critical object was taken as 25% (Guler and Onaygil, 2003a).

According to Adrian's visibility equations, visibility level of the critical object which is on the road surface defined by Adrian (1989).

$$VL = \Delta L_{actual}/\Delta L_{threshold} \quad (1)$$

where, VL: Visibility level, ΔL_{actual}: the luminance difference between the target and its background for the real road conditions, $\Delta L_{threshold}$: The luminance difference needed for minimal visibility, between a target of certain angular size and its background (Guler and Onaygil, 2003a).

According to the studies hitherto, the visibility level should be higher than 7 (seven) in order to get sufficient visual conditions (Adrian, 1987, 1993, 1995; Lecocq, 1997; Dijon and Maldague, 1998). However, since it is related with contrast directly, the visibility level can reach to a high value by decreasing uniformity ratios on the road. For the driver comfort and safety, decreasing of uniformity ratios on the road is an unacceptable condition (Guler and Onaygil, 2003a).

This study establishes a correlation between the road

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and photometrical values of the critical objects on the road obtained using measurement tools over the photo using image processing techniques with the qualitative values of the pixels. This correlation makes it possible to calculate the glare of the road and the critical object over the road. Then, also in consideration of the glare values and other factors influencing visibility, the visibility of the critical object is calculated in the software. Also, thanks to the developed software, it has become possible to calculate the visibility of traffic signs, lines, barriers, physical deformations over the road, which affect the traffic.

MATERIALS AND METHODS

Visibility level calculation parameters

The visibility level, VL, quantises the observer's ability to see an object more or less easily. It is linked with various parameters related to the object and the observer. The parameter in relation to the object is the 'contrast', ΔL, between the target and its background. The parameters related to the observers are more complicated, as they include the observer's visual clarity, the luminance level, the time of observation and the angular dimension that the object subtends (Bacelar et al., 1999).

The actual luminance difference between the target and its background can be calculated from (Guler and Onaygil, 2003a).

$$\Delta L_{actual} = L_f - L_b \tag{2}$$

Where, L_f: The target luminance (cd/m^2), L_b: the background luminance (cd/m^2).

According to Adrian's theory, this threshold value (ΔLe) is taken from empirical equations.

$$\Delta L_e = k \cdot \left(\frac{\sqrt{\Phi}}{\alpha} + \sqrt{L} \right)^2 \cdot \frac{\alpha(\alpha, L_f) + t_g}{t_g} \cdot F_{cp} \cdot AF \tag{3}$$

Where, k: factor for the probability of perception (k = 2.6 for 100% probability), Φ: Luminous flux function (lm), L: luminance function (cd/m^2), F_{cp}: contrast polarity factor, AF: age factor
$a(a; L_b)$: Parameter depending on size of target and background luminance, t_g: observation time (s)

Luminous flux function (Φ) and glare function (L) are calculated with the help of the experimental values obtained by Adrian, Aulhorn, Blackwell and Berek. Luminous flux and flare function change depending on the background glare (Semiz, 2006).

Fcp is a correction factor that has to be used in the even of negative contrast between the object and the background. Its values depend upon the background glare and the angular size of the object. $F_{cp} = 1$ where the contrast is positive (Semiz, 2006).

$$F_{cp}(\alpha, L_f) = 1 - \frac{m \cdot \alpha^{-\beta}}{2.4 \cdot \Delta L_{pozt=2}} \tag{4}$$

The following formula is used to find the values valid for observation times under two second (Semiz, 2006).

$$\frac{a(\alpha, L_f) + t_g}{t_g} \tag{5}$$

This term is taken as 1 if the observation time is over two seconds. Since the eye permeability reduces by time, glare difference threshold increases as the driver's age goes up (Semiz, 2006).

23 < Age < 64 for age factor:

$$AF = \frac{(Age - 19)^2}{2160} + 0.99 \tag{6}$$

64 < Age < 75 for age factor

$$AF = \frac{(Age - 56.6)^2}{116.3} + 1.43 \tag{7}$$

The coefficient 2.6 was used to adapt these experimental results with those results when the object is seen at a 100% probability (Adrian, 1987). If visibility level values take a positive value the object has a positive contrast and a negative value if it has a negative contrast. Therefore, absolute values should be considered when comparing visibility level values with each other (Semiz, 2006).

Working principle of the system

A computer program was developed using Adrian's visibility equations for calculating the visibility level of an object on the road (Guler and Onaygil, 2003b). Working principle of the system is given in Figure 1.

The developed software enables the testing of the visibility of the photographed critical object using image processing techniques. The dimension of the critical object used in this system is 20 × 20 cm. The reflection coefficient of the critical object measured by a refractometer is 0.25. The voltage of the lamps used in road illumination is 250 W, with the luminous flux being 33, 000 lumen. The luminous intensity curves of road luminaire are given in Figure 2.

The glare of the photographed critical object using image processing techniques can be calculated thanks to the developed software. To measure the glare of the road and the object over the road, the road and the object are photographed from various points and illumination level values are measured by a luxmeter. A correlation was found between the measured illumination level values and the qualitative values of pixels over the photo are given in Figure 3. Utilizing this correlation, it becomes possible to calculate the illumination level of the road and the object.

The reflection coefficient and thus the glare changes depending on the material by which the road is made. To learn the reflection coefficient of the road to be measured and analyzed, reflection coefficients of various points over the road are measured using a refractometer and the obtained values are entered into the reflection coefficient section in the developed software menu after the average reflection coefficient of the road is taken.

The following formula is used to calculate the glare of the road and object with known illumination level and reflection coefficient.

$$L = q \cdot E \tag{8}$$

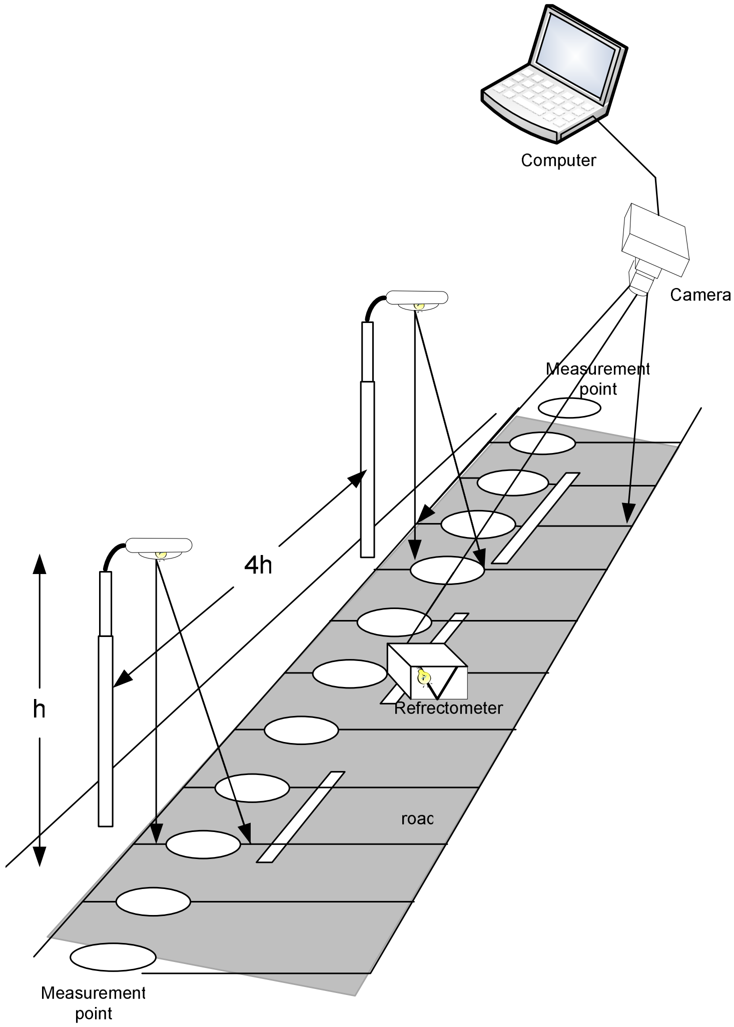

Figure 1. Working principle of the system.

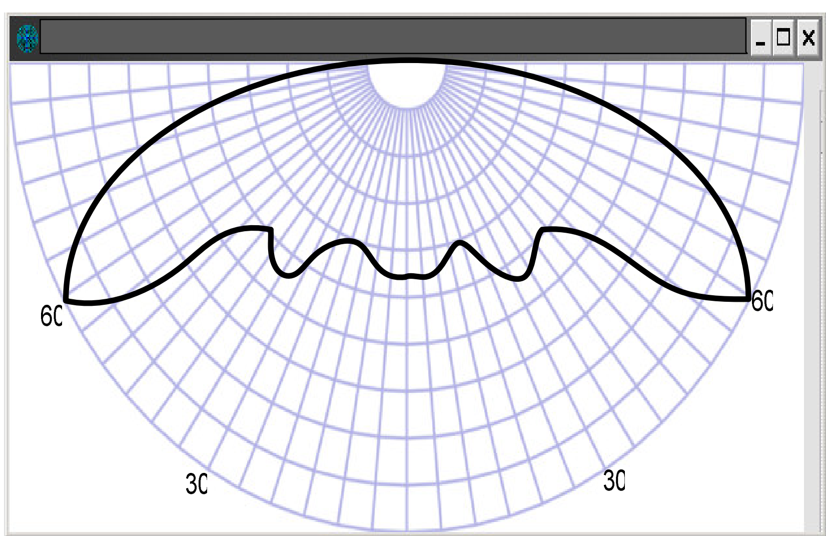

Figure 2. The luminous intensity curves of road luminaire.

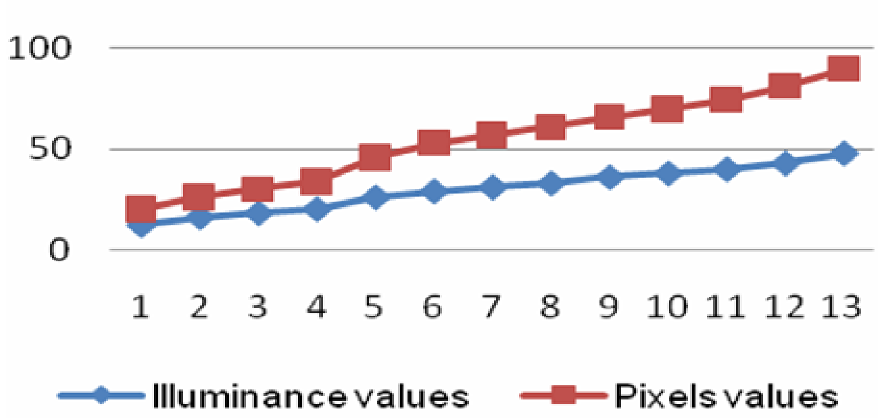

Figure 3. Comparison of illuminance values and pixels values.

Table 1. The effect of the age of the object over the visibility level.

Road luminance	Object luminance	Age	Angular size of the object	Visibility level
1.67	2.79	25	20	28.87
1.67	2.79	30	20	27.78
1.67	2.79	35	20	26.22
1.67	2.79	40	20	24.34
1.67	2.79	45	20	22.30
1.67	2.79	50	20	20.25
1.67	2.79	55	20	18.28
1.67	2.79	60	20	16.43
1.67	2.79	65	20	14.27
1.67	2.79	70	20	9.77

where L : Luminance, q : Luminance factor, E : Illumination level.

$$q = \frac{\rho}{\pi}$$

(9)

Where, q: Luminance factor, ρ: Reflect factor

$$L = \frac{\rho \cdot E}{\pi}$$

(10)

Visibility level changes by age and the angular size of the object. These variables need to be entered into the developed software. Program interface is given in Figure 4.

Visibility of the critical object is tested over the road in Figure 5. The road has M2 standards by international standards. Average reflection coefficient of the critical object and the road is measured using a refractometer. The road's average reflection coefficient is measured as 0.13 and the critical object's reflection coefficient is measured as 0.25.

The effect of the age factor and the angular size of the object over the visibility level of the critical object are studied using the developed software. The effect of observer's age over the visibility level is shown in Table 1 and Figure 6.

RESULTS AND DISCUSSION

Road illumination design calculations are created during the project stage of the system. After the road illumination is done, the road illumination might not give the required photometric conditions for reasons like environmental conditions, time-dependent deformation, wear, dust formation and faulty assembly. Photometric conditions failing to be in the desired levels affect the visibility of the objects over the road.

In recent years, visibility level is being used to measure the visibility of objects over the roads. The developed project allows the calculation of the visibility level of an object with a known reflection coefficient. It becomes possible to measure how much the traffic signs and deformations that prevent the road traffic affect the traffic.

With the software developed in this study, visibility of critical objects is tested according to the visibility level

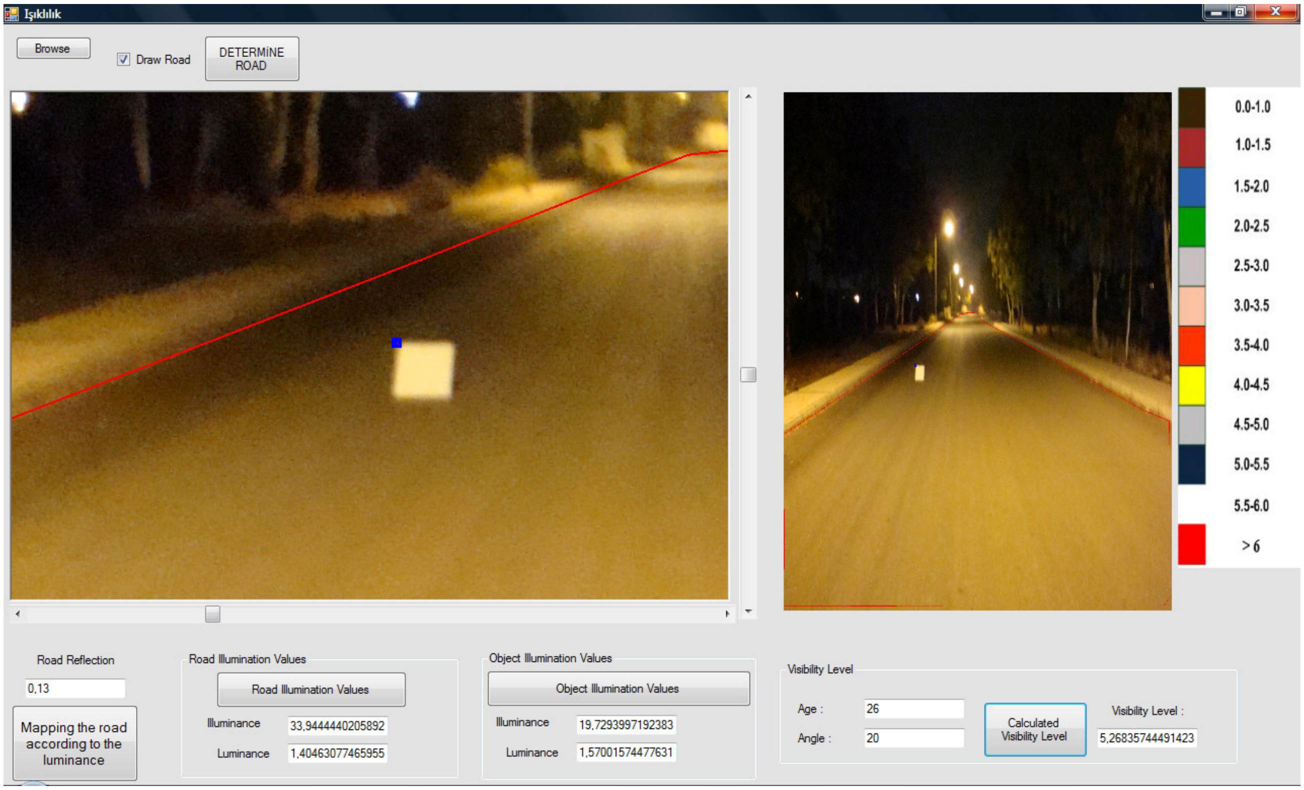

Figure 4. Program ınterface.

Figure 5. Visibility of the critical object is tested over the road.

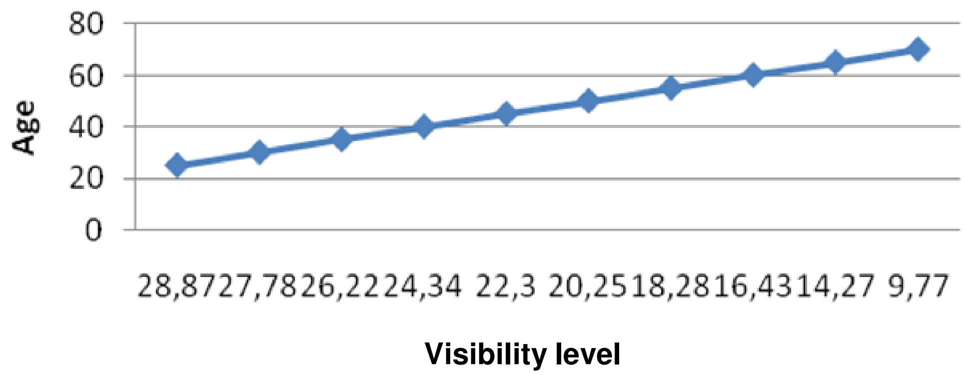

Figure 6. The effect of the age of the object over the visibility level.

Table 2. The effect of the angular size of the object over the visibility level.

Road luminance	Object luminance	Age	Angular size of the object	Visibility Level
1.67	2.79	26	5	6.49
1.67	2.79	26	10	15.34
1.67	2.79	26	15	22.78
1.67	2.79	26	20	28.70
1.67	2.79	26	25	33.42
1.67	2.79	26	30	37.24
1.67	2.79	26	35	40.39
1.67	2.79	26	40	43.01
1.67	2.79	26	45	45.23
1.67	2.79	26	50	47.13

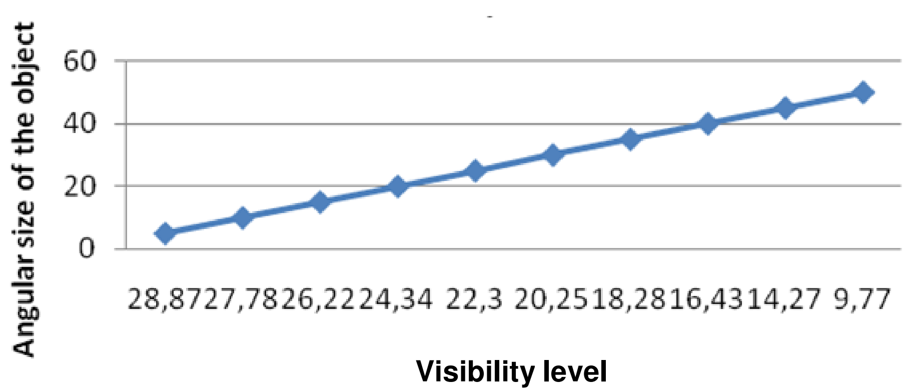

Figure 7. The effect of the angular size of the object over the visibility level.

using image processing techniques over the photo of an illuminated road without using any photometric measurement tools.

The study also focuses on the effects of factors like glare, age and the angular size of the object influencing visibility on the visibility level. Table 2 and Figure 7 show the effect of the angular size of the object over the visibility level.

Conclusions

Visibility level measurements were prepared for physiological vision conditions. When the software was prepared, eye malfunctions and color blindness was not taken into consideration. These malfunctions affect vision conditions. In this case, the visibility factor also changes. Especially, preparation of special simulation conditions for color blindness and reconsideration of their abilities to see objects, it may be possible to emphasize advantages and disadvantages with respect to sight level of color blindness. If the standards prepared for artificial lighting conditions are adapted to the system, not only the visibility level of critical object illuminated by road lighting, but also critical objects illuminated by all lighting conditions will be tested.

REFERENCES

Adrian W (1987). Visibility Levels Under Nighttime Driving Conditions, Journal of the Illuminating Engineering Society, Summer, pp. 3-12.

Adrian W (1989). Visibility of Target: Model for Calculations, Lighting Res. Technol., 21: 181-188.

Adrian W (1993). Visibility Levels in Street Lighting: An Analysis of Different Experiments, J. Illuminating Eng. Soc., 22: 49-52.

Adrian W, Gibbons R (1995). Fields of Visibility of the Nighttime Driver, Light Eng., 3: 1-12.

ANSI/IESNA RP-8 (2000). American National Standard Practice for roadway Lighting.

CIE Publication No. 115 (1995). Recommendations fort he Lighting Roads for Motor and Pedestrian Traffic.

Dijon JM, Maldague L (1998). Quality Criteria for Road Lighting and Uniformity Levels? Or Visibility? 2nd National Illumination Congress' 98, Istanbul, Turkey, pp. 138-141.

Fiorentin P, Scroccaro A (2009). The importance of testing road lighting plants: a simple system for their assessment. International Instrumentation and Measurement Technology Conference. Singapor.

Lecocq J (1997). Visibility in Road Lighting Correlation of Subjective Assessments with Calculated Values, Lux Eur., 97: 22-36.

Guler O, Onaygil S (2003a). A New Criterion for Road Lighting: Average Visibility Level Uniformity. J. Light and Visual Environ. 27(1): 39-46.

Guler O, Onaygil S (2003b). The Effect Of Luminance Uniformity On Visibility Level In Road Lighting. Lighting Res. Technol., 35(3): 199-215.

Semiz SB (2006). Examination Of Design Criteria in Controlled Road Lighting Installations Upon The Basis Of Visibility. Istanbul Technical University, Institute of Science and Technology, M.Sc. Thesis, 136, İstanbul.