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Research Article

The Determination of the Uniformity in Road Lighting Using Artificial Neural Networks

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Abstract:

To ensure that drivers can travel safely, it is necessary to provide good visibility conditions of the road lighting. Thanks to good road lighting, accident rates will decrease, pedestrians' safety will be increased and drivers will be able to travel comfortably. Road lighting standards are included in CIE's 115 "Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic". According to this standard, there are 6 different lighting classes according to the road definition. There are different lighting standards for each class. These are: average luminance (L_{ave}), overall uniformity (U_0), longitudinal uniformity (U_1), disability glare (TI), lighting of surroundings (SR). Uniformity is a measurement of how equally light is distributed on the road. Overall uniformity ratio is of minimum luminance to mean luminance and longitudinal uniformity is the ratio of minimum luminance to maximum luminance. If the uniformity is good, all objects on the road can be easily seen by drivers. In this study, a new method was used to measure the uniformity of the road. Unlike classical methods, image processing and artificial intelligence techniques are used to calculate luminance and uniformity. The uniformity results of the test roads were examined to meet the standards according to the road class.

1. Introduction

The main purpose of road lighting is to ensure that drivers and pedestrians can travel safely and comfortably. Improving road lighting is a way to reduce the number of fatal and personal injury accidents[1-3].

Road lighting standards are included in CIE's 115 "Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic" [4, 5]. According to this standard, there are 6 different lighting classes according to the road definition. There are different lighting standards for each class. These are, average luminance (L_{ave}), overall uniformity (U_0), longitudinal uniformity (U_1), disability glare (TI), lighting of surroundings (SR).

Table 1. *Road Lighting Standards [4, 5]*

Lighting classes	L_{ort}	U_o	U_1	TI (%)	SR
M1	≥2.0	≥0.4	≥0.7	≤10	≥0.5
M2	≥1.5	≥0.4	≥0.7	≤10	≥0.5
M3	≥1.0	≥0.4	≥0.6	≤15	≥0.5
M4	≥0.75	≥0.4	≥0.6	≤15	≥0.5
M5	≥0.50	≥0.35	≥0.4	≤15	≥0.5
M6	≥0.30	≥0.35	≥0.4	≤20	≥0.5

Overall uniformity [6]: Overall uniformity is a measure of how evenly lit the road surface is. The overall uniformity is established by dividing the minimum of luminance (L_{min}) by the average luminance (L_{ave}) [7]:

$$U_0 = L_{min}/L_{ave} \quad (1)$$

Longitudinal uniformity [8]: Longitudinal uniformity is a measure to reduce the intensity of bright and dark banding on road lit surfaces. In design it is expressed as the ratio of the minimum to maximum luminance within the lane of travel [7]:

$$U_1 = L_{min}/L_{max} \tag{2}$$

wherein L_{ave} the average road surface luminance, L_{min} and L_{max} are the minimum and maximum luminance on the central lane line passing through the observer position [6].

It is important to ensure uniformity when designing lighting in areas where artificial lighting is needed [9]. Thus, dark and light areas can be avoided [10]. In addition, lighting homogeneity should be provided for safety and comfort indoors and outdoors [11]. The uniformity of light is the most useful parameter that can define the quality of the field with a single value [12].

Higher luminous smoothness provides better passenger visual comfort [8]. It is desired that the level of illumination is the same on the illuminated surface, that is, the uniformity factor is 1. If uniformity is not achieved, the eye will strive to adapt itself to different levels of lighting and will be tired quickly [13, 14].

Special studies are carried out to ensure uniformity in road lighting. For example, Hu and Qian [15], in their study, they designed a special lens for LED luminaires used in lighting to provide high uniformity on the road surface. As a result of this study, overall illuminance 0,90; longitudinal uniformity has reached 0.85. Coşkuner and Öztop [14] stated that it is necessary to use diffuse beams of light sources to ensure uniformity and place them close together. Another study emphasized that it is necessary to increase the number and strength of LED lamps to increase uniformity[10].

Luminous values of many points in the measurement area have an effect on uniformity indices. Therefore, any changes in this area will affect the illumination homogeneity. Many parameters, including lighting distribution, area geometry, lamps, luminaire and electrical properties, will affect uniformity. Many of these factors have an impact, both initially and over time. Because changes in these factors are difficult to predict [16].

In this study, a software was used to calculate the overall uniformity and longitudinal uniformity on the road by using image processing and artificial intelligence techniques.

2. Methods and Materials

In this study, a software based system has been developed to calculate overall uniformity and longitudinal uniformity. The system consists of 3 basic stages.

In the first stage, the road was photographed according to the determined standards. The image acquisition system has been developed to establish a standard for the photographs taken. Thus, it will be provided to take photographs on the same standards on different roads.

In the second stage, the photographs taken are transferred to the developed software. Using the software, the measurement areas of the road were determined from the images and this area was removed from the image and transferred to a new image file.

In the third stage, the luminance of the road was calculated. For this, reference points have been determined on the road; a correlation is established between the luminance of these points and the pixel values (R, G, B). The luminance of the road is calculated according to the observer by using artificial neural networks [1], one of the artificial intelligence techniques for this correlation. This stage was carried out in the previous study [17].

At the last stage, overall uniformity and longitudinal uniformity are calculated with the developed software. Minimum uniformity was analysed according to the road class. The flow chart of the system operation is given in Figure 1.

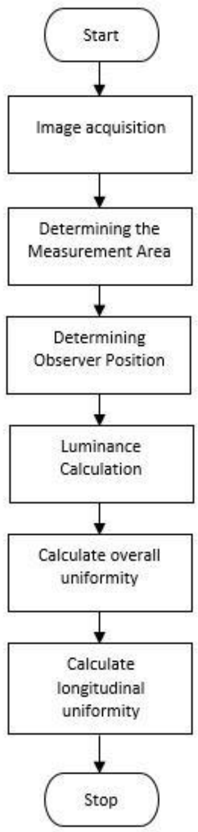

Figure 1. *Flow-chart of the system operation*

2.1. Image Acquisition System

An image acquisition system has been created to take a photo of the road. This system consists of tripod, camera and lens (Canon Eos 200D, Lens: 18-55mm). Some precautions have been taken when taking pictures to avoid affecting measurements. The flash equipment of the image acquisition system has not been used, and the manual settings of the camera are used. This prevents the machine from correcting the automatic photo after the photo is taken. The .raw file format is also used as a photo format. Thus, the procedures were performed on the original photo.
The image acquisition system is set to a height of 1.5m from the ground and photographed at the same angle as the luminance meter. Figure 2 shows the image acquisition system.

Figure 2. *Image acquisition system*

2.2. Determining the measurement area of the road

In this step, the first photo of the road is uploaded to the system. Then the corners of the measurement areas on the road are marked. The system saves the space between these points as a new photo as a measurement area. Figure 3 shows the process of "Determining the Measurement Area of the Road". The developed system determines the observer at the midpoint of each road lane.

2.3. Luminance calculation

Using the artificial neural network method, the luminance value was calculated according to the observer. An artificial neural network model was designed with three input (R, G, B) nodes, three hidden layers and one output (luminance) layer. There are 2-4-5 nodes in three hidden layers. In this design, the backpropagation algorithm network model is used [17]. artificial neural network model is shown in Figure 5.

Figure 3. *Determining the Measurement Area of the Road*

Figure 4. *The position of the observer.*

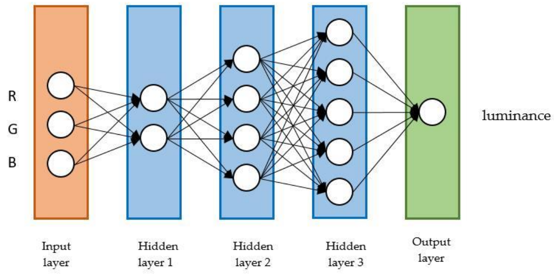

Figure 5. *Artificial neural network model*

3. Experimental Study

Roads have been selected in Antalya, Konyaaltı district in accordance with M3 road lighting class. Although the roads provide the same standard, it has different features. Asphalt structure, homogeneity, number of luminaires, lamp feature, pollution rate of lamps, efficiency of lamps, interval between luminaires differ. The roads are shown in Figure 6. The photos of the test roads were transferred to the software and the measurement areas on the road were determined by the software. Luminance were calculated according to the observer. The calculated luminance is shown in Table 2.

Figure 6. *Test Roads*

Table 2. *Luminance on the Road*

ID	Road ID					
	Road 1		Road 2		Road 3	
	Lane A	Lane B	Lane A	Lane B	Lane A	Lane B
1	2,54	2,63	1,51	1,85	2,47	2,51
2	2,62	2,79	1,92	2,01	1,95	2,32
3	2,2	2,32	1,1	1,95	1,62	2,02
4	1,53	2,01	0,69	1,2	1,24	1,95
5	1,86	1,55	0,59	1,1	1,97	2,22
6	0,55	0,10	0,55	0,95	1,82	2,19
7	0,68	0,15	0,44	0,75	1,07	1,65
8	0,65	0,17	0,43	0,67	1,19	1,55
9	0,65	0,29	0,35	0,55	1,29	1,65
10	0,72	1,65	0,33	0,46	1,22	1,55
11	0,66	1,90	0,21	0,32	1,67	1,92
12	0,71	2,1	0,39	0,44	2,41	2,77
13	1,36	2,12	0,43	0,67	3,07	3,35
14	1,52	2,02	0,66	0,88	3,67	3,95
15	1,37	1,95	0,92	0,99	3,01	3,65
16	0,87	1,85	0,96	1,01	2,24	2,65

Uniformity was calculated according to the luminance of the road. Uniformities of roads are shown in Table 3.

Table 3. *Uniformity of Roads*

Road ID		Luminance (cd/m^2)			Uniformity	
		L_{ave}	L_{min}	L_{max}	U_0	U_1
Road 1	Lane A	0,28	0,55	2,62	0,43	0,21
	Lane B	1,60	0,10	2,79	0,06	0,04
Road 2	Lane A	0,72	0,21	1,92	0,29	0,11
	Lane B	0,99	0,32	2,01	0,32	0,16
Road 3	Lane A	1,99	1,07	3,67	0,54	0,29
	Lane B	2,37	1,55	3,95	0,65	0,39

The measured paths are the M3 lighting class and the standard required for longitudinal uniformity (U_1) is 0.6 and the desired value for overall uniformity (U_0) is 0.4. The longitudinal uniformity and overall uniformity rankings are the same from the best to the worst in all three ways: Road ID C, Road ID A, Road ID B. 50% of the lanes on the tested roads meet the desired longitudinal uniformity condition. For overall uniformity, no lane in any roads could provide the desired value.

4. Conclusions

Lighting should be uniform all the road. Road lighting with low homogeneity has a negative effect on human psychology. It prevents drivers from traveling comfortably and causes fatigue. These reasons increase the probability of an accident at night.

Generally, only average luminance is taken into consideration in road lighting. Although it is in the standards, uniformity is not taken into consideration sufficiently. If good lighting is desired, it should be taken into consideration in uniform as much as the luminance.

Uniformity can change over time. Decreases in the efficiency of lamps, environmental factors and incorrectly planned lighting designs affect uniformity. Therefore, periodically, the luminance in the road should be measured and uniformity should be calculated.

Uniformity can be measured easily and quickly with the system developed in this study. Lighting results can be improved with the results obtained here: Lighting results can be improved with the results obtained here: The location of the luminaires can be adjusted again, environmental factors affecting the lighting (tree, pollution rates) can be kept under control.

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