Visibility Measurement Technique Using Photographic Images

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Abstract

Nighttime traffic accident rates are considerably higher than daytime accident rates. There are several reasons for the unbalanced accident rates during the night; one being that an average person is poorly equipped to see adequately at night. Visual performance and traffic safety are highly correlated to the amount of visual input, which we can receive from the road and its immediate environment. Therefore, any quality judgement for the lighting system is based on the visibility criteria. In this article, an experimental method is introduced to measure the visibility of a small target and compare the results with the Illumination Engineering Society (*IES*) which is a recommended analytical method. Geometric data of the experimental field was entered in a computer and the visibility level (*VL*) of the small target was calculated by using the Keck's program at 10 standard points between the poles. The image of the small target was recorded at the same 10 standard points and all the recorded images were loaded to the computer and analysed by using picture analysis program developed by using Visual Basic algorithm in our laboratory. After the calculations, the theoretical and experimental results were plotted and compared.

1. Introduction

Fixed roadway lighting plays an important part in safe driving at night. Since automobile headlights do not light a distance that is adequate for safe stopping at night. To provide safe driving at night, different design methods for roadway lighting was developed to obtain better visibility and visual comfort. The first time roadway lighting were desined, it was based on the amount of light striking the surfaces of the pavement (illuminance). However, it was later found that the brightness of a pavement related to the amount of light that is reflected from it (luminance). Since then, it has been proved that the ability to see an object at night is based not on the light that is striked from the object, but on the difference in the brightness between the target and its background (contrast).

The first lighting research was started in the 15th century, when the citizens of London and Paris began to carry lanterns at night. In 1866, the control of roadway lighting by government agencies began in Paris. The first significant lighting research was conducted by Sweet in the 1910's. He studied the disability glare under the supervision of Railroad Warehouse Commission at Madison, Wisconsin. Subsequently, in 1914, an extensive research project was conducted in Philadelphia by Preston Miller. Waldram of England continued this reseach in the late 1930's.

Since 1947, the Roadway Lighting Committee (*RLC*) of the Illuminating Engineering Society of North America (*IESNA*) has published Recommended Standard Practices (*RP*) which includes the roadway lighting design criteria. In the draft *RP-8*[1], the concept of *STV* is proposed for high-speed roadway lighting design. The latest computer program that theoretically calculates roadway lighting design using *STV* method was developed by Keck[2].

Lewin *at. al,*[3] developed a program for accuracy analysis of video-based photometry. They used charge coupled device *(CCD)* camera system to obtain accurate and reliable data for automotive lighting device. Cuvalci *at. al,*[4] developed an experimental system to measure visibility distribution on roadway for the small target (Figure 1). The experimental system was designed based on the RP-8 criteria. Cuvalci *at. al* was used a *3CCD* video camera to obtain accuread data for small target.

In this paper, a computer program (picture analysis program) which has been developed in our laboratuary using Visiul Basic calculates visibility distribution from the recorded video images of the small target at the 10 standart points between the poles. Keck's program which is based on RP-8 was also run for the same experimental field. The experimental and theoretical results were plotted and compered.

2. Theoretical Visibility

The American National Standard Practice for Roadway Lighting (RP-8)[1] presents a method to calculate fixed light for roadways, adjacent bikeways, and pedestrian ways. With good vision provided by roadway lighting, efficient night use can be made of the large investments in roadways and motor vehicles. Keck program[2], which was designed based on RP-8, calculates visibility level by using the following formula:

$$VL = (Lt - Lb) / DL_4 . \tag{1}$$

Where *VL* is visibility level
        Lt is target luminance at middle point of a target
        Lb is background luminance
Background luminance is obtained by averaging the background luminance at the immediate middle point of the upper and lower edges of the target (*Lb=(Lb1+Lb2)/2*) as seen in Figure 1, and *DL₄* is an adjustment factor. These calculations are performed using an 18 x 18-cm target with a 20% reflective surface (*STV* requirement).

3. Visibility calculation from Video Images

A *3CCD* SONY video camera was used with a Hi8 video tape to record the target images. The *3CCD* camera system employs high density three-chip precision, and each *CCD* image includes a total of 410,000 pixel. An image is separately projected by the lens into three primary colors; red, green and blue (*RGB*). An experimental system was designed according to rules of RP-8 (1). Video images were recorded at the 83-meter distance and 1.628 meter above the small target. The small target image was placed at the center of the camera frame to satisfy one-degree down angle[4].

To build the small target, two aluminium pieces were connected to each other at a 90-degree angle. Two other holders were designed to mount red Light Emitting Diods (*LED*) above and to

either side of the target at 45-degree angels to the target's horizontal surface. The *LED*'s were placed in cylindrical tubes to shield the target surface from their light. They were used as reference markers to determine exact boundaries of the target[4]. To obtain the STV target, an 18 x 18-cm, 20% reflective grey scale paper was placed on the vertical surface of the foundation as a diffuse reflective surface as seen Figure 1.
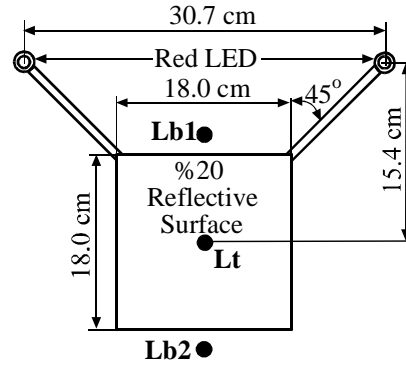
Figure 1 Small target with measurements.

The small target images were loaded in a computer using a video editing system. From the images, the visibility values were calculated by the picture analysis program using the following formula as a percent:

$$Visibility(\%) = \frac{Lt - Lb}{256} * 100.$$ (2)

The visibility values were converted to percentages according to the following conditions:
- If a white object was on a white background or a black object was on a black background, then visibility percentage was zero.
- If a white object was on a black background or a black object was on a white background then visibility percentage is 100.

3.1. Co-ordinate Definition

After loading the video images of the small target to the computer, each image was loaded to the screen one by one by the picture analysis program (Figure 2). When the image is on the screen, the mouse clicks on the red *LED* of the small target to calculate *x1, x2, y1* and *y2* co-ordinates. At the same time, the program transfers the small target from the picture with enough background to another picture box. Then, the center of the small target (center of the reflective surface) was calculated by the following algorithm:

$$Dis = \left[(x1 - x2)^2 + (y1 - y2)^2 \right]^{1/2}$$

$$Ratio = Dis / 30.7$$

$$Xc = (x1 + x2) / 2$$

$$Yc = (y1 + y2) / 2 + Ratio * 15.4$$

Where 30.7 cm is the distance between the two red LED, and 15.4 cm is the distance between the center of the small target and red LED as seen in Figure 1. To obtain the boundaries of the small

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target, the distance between the center and the boundaries were multiplied with *Ratio* and than the obtained values were added or subtracted to the center co-ordinate of the small target.
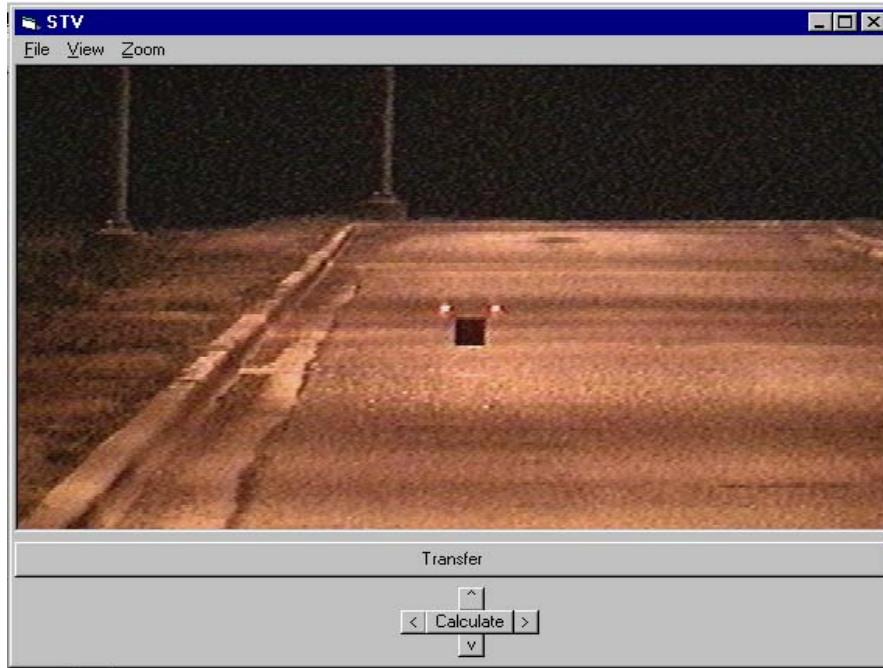

Figure 2 Picture with the small target.

3.2. Target Zoom

From the picture, the small target was transferred to another picture box with a background. During the transformation, the color image was zoomed for better recognition the boundaries of the small target, and at the same time, it was constructed to a black and white picture. To obtain the black and white picture, each pixel of the color picture was separated into three main colors; red, green, and blue. The arithmetic average of the main colors (*(R+G+B)/3*) was calculated for each pixel and recorded at the same pixel to obtain grain scale picture as follows:

$$c = colorRGB$$
$$Blue = Int(c / 65536)$$
$$c = c - Blue * 65536$$
$$Grean = Int(c / 256)$$
$$\text{Re}d = c - Grean * 256$$

In the zoom box a frame was defined at the original target size and data (pixel) reading co-ordinates (sample lines) for visibility calculations that was marked on the background and on the reflective surface. If the locations of the sample lines were not in the right places, the frame will move up, down, right and left by using the arrow buttons to adjust the small target in the frame as seen in Figure 3. The adjustment provides the right co-ordinate to read data.
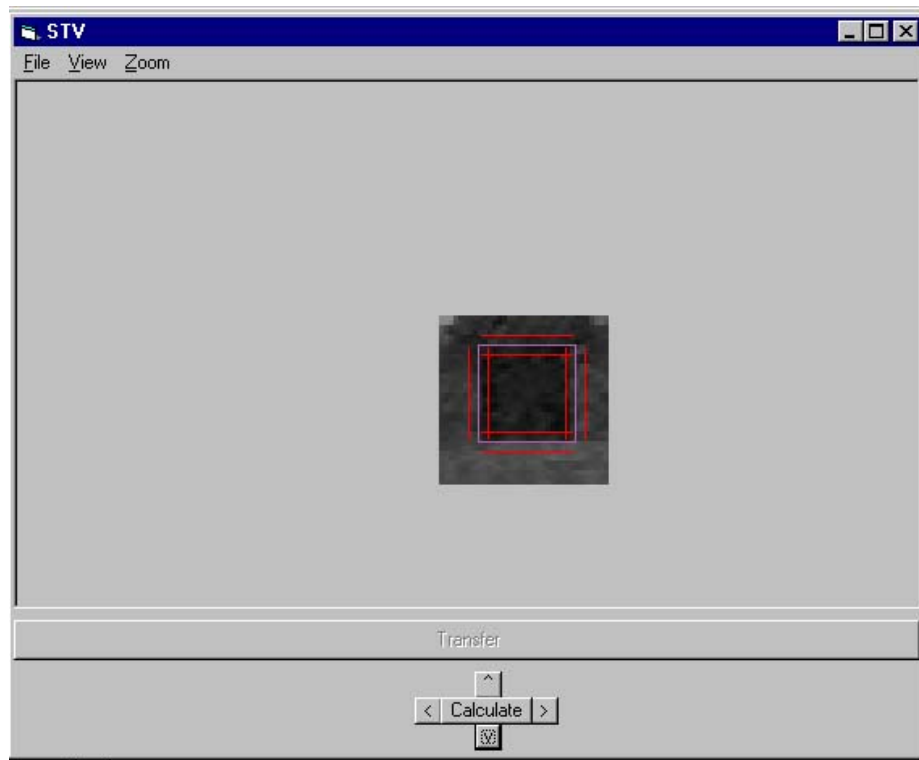
Figure 3 Zoom box.

3.3. Luminance Calibration

During the video image recording in the experimental field, the brightest point in all the images was the red LED's light. One of the red *LED* luminance was attenuated in order to calibrate video images pixel by pixel. In the image, the maximum pixel value (255) should be matched to the maximum luminance value of the red *LED* that is measured by the luminance probe before and after the experiment. To obtain the second attenuated red *LED*'s pixel value, the cursor is clicked on the red *LED*. Now, two pixel region values and their corresponding luminance values are known. By using these four values, the picture can be calibrated using linear interpolation algorithm.

4. Result and discussion

The program reads the pixel values at the marked points as seen in Figure 3 and calculates visibility by using the Equation (2). The spectral density of the target with background is also calculated and presented in Figure 4. The pixel distribution of the picture with target presents as seen in Figure 5. From the Figure 5, pixels around the target and red LED sharply changed from one value to another. The picture analysis program flow chart was shown in Figure 6.
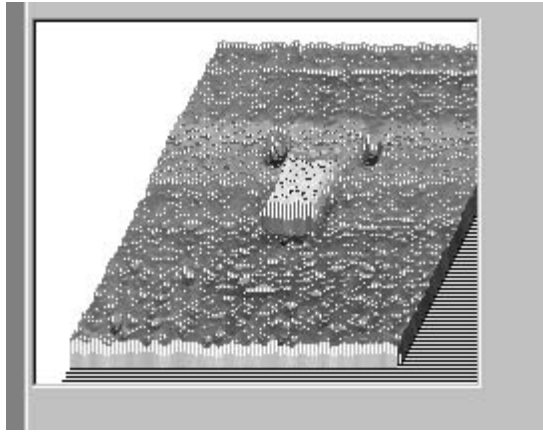
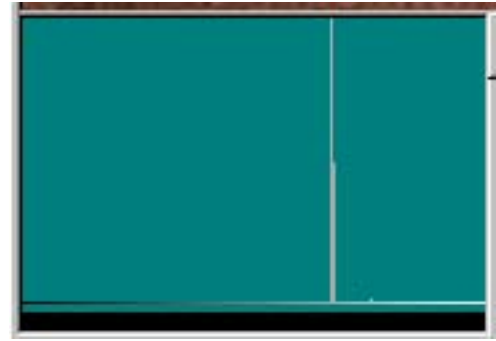Figure 4 Pixel distribution of the picture with target.

Figure 5 Spectral density.

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                        ┌─────────────────────┐
                        │        START        │
                        └─────────────────────┘
                                  │
                        ┌─────────────────────┐
                        │    OPEN FILE BOX     │
                        │   (TARGET IMAGES)    │
                        └─────────────────────┘
                                  │
                        ┌─────────────────────────────┐
                        │  CLICK ON THE RED LED'S      │
                        │  TO OBTAIN X1, X2, Y1 AND Y2 │
                        │  CO-ORDINATES AND RATIO      │
                        └─────────────────────────────┘
                                  │
  ┌────────────────┐    ┌─────────────────────────────┐
  │ PRINT THE PIXEL│    │  TRANSFER THE TARGET WITH    │
  │ DISTRIBUTION OF│    │  BACKGROUND TO ANOTHER       │
  │  THE PICTURE   │    │  PICTURE BOX AS BLACK AND WHITE│
  └────────────────┘    └─────────────────────────────┘
                                  │
                        ┌─────────────────────────────┐
                        │  FOR FINE REPLACEMENT, USE   │
                        │  DOWN, RIGHT AND LEFT BOTTENS │
                        └─────────────────────────────┘
                                  │
  ┌────────────────┐    ┌─────────────────────────────┐
  │     SHOW       │    │  READ PIXEL VALUES AT THE CENTER│
  │ THE SPECTRAL   │    │  AND OUT SIDE OF THE UP AND DOWN│
  │   DENSITY      │    │  EDGES OF THE TARGET         │
  │  AS A GRAPH    │    │                              │
  └────────────────┘    │  Lt, Lb1 AND Lb2;            │
                        │  Lb=(Lb1+Lb2)/2              │
                        └─────────────────────────────┘
                                  │
                        ┌─────────────────────────────┐
                        │  CALCULATE VISIBILITY        │
                        │  VISIBILITY=(Lt-Lb)*100/256  │
                        └─────────────────────────────┘
                                  │
                        ┌─────────────────────────────┐
                        │   PRINT AND GRAF OUTPUTS     │
                        └─────────────────────────────┘
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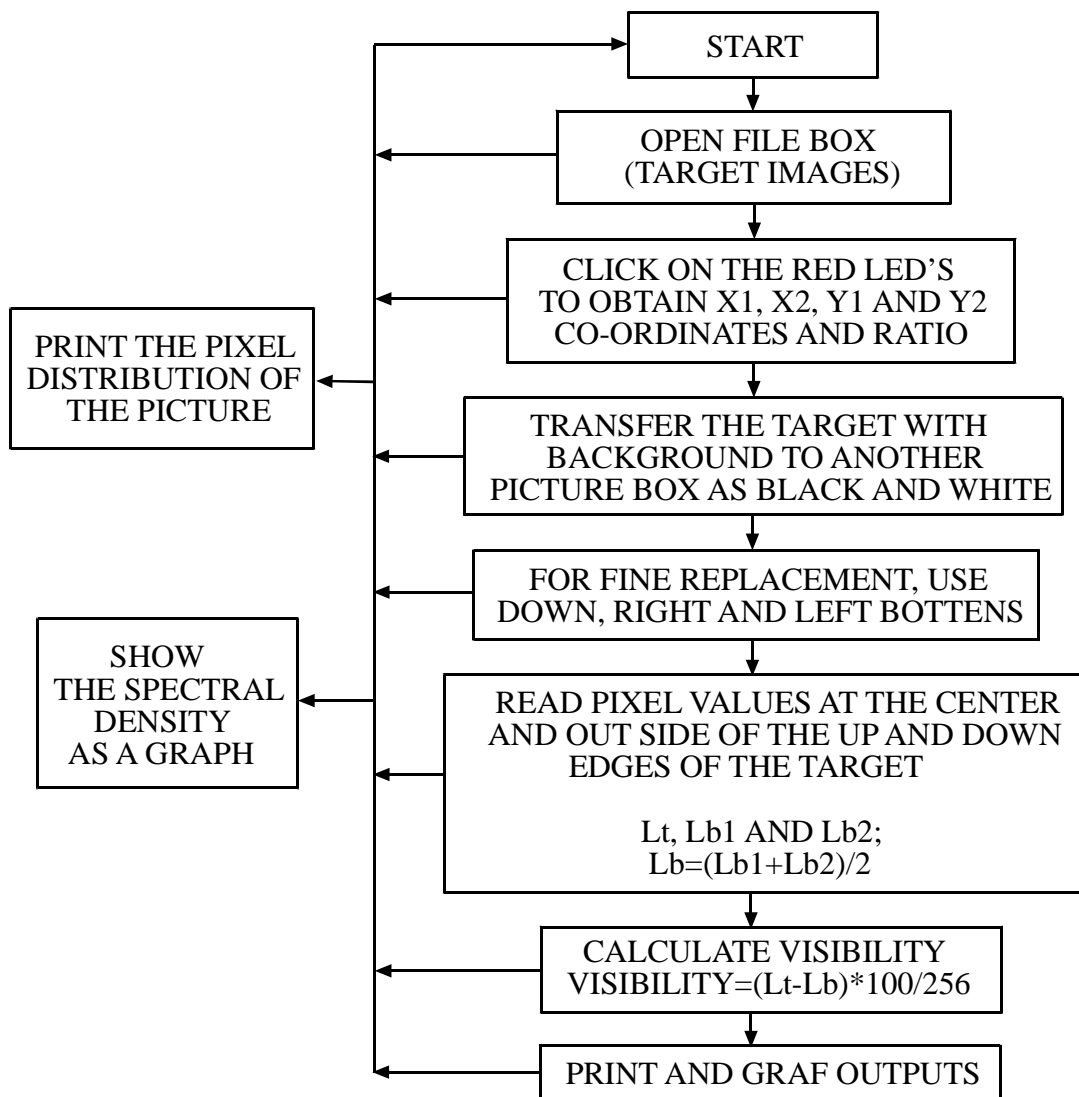
Figure 6 Flow chart of the picture analysis program.

Experimental field geometric properties were entered into the Keck's program to calculate the theoretical visibility values at the 10 standard points between two poles. Figure 7 shows the theoretical visibility distribution between the two poles. As seen from the figure, visibility of the small target on the roadway changes nonlinearly and the small target visibility value at the second and third point is lower than the others. In other words, the small target is less visible at the second and third point between the poles. The small target images were recorded at the same 10 standard points with theoretical calculations. Experimentally obtained visibility distribution from the video images also changes nonlinearly between the poles as seen in Figure 8. Figure 8 also shows that the visibility value of the small target is less at the second and third point.
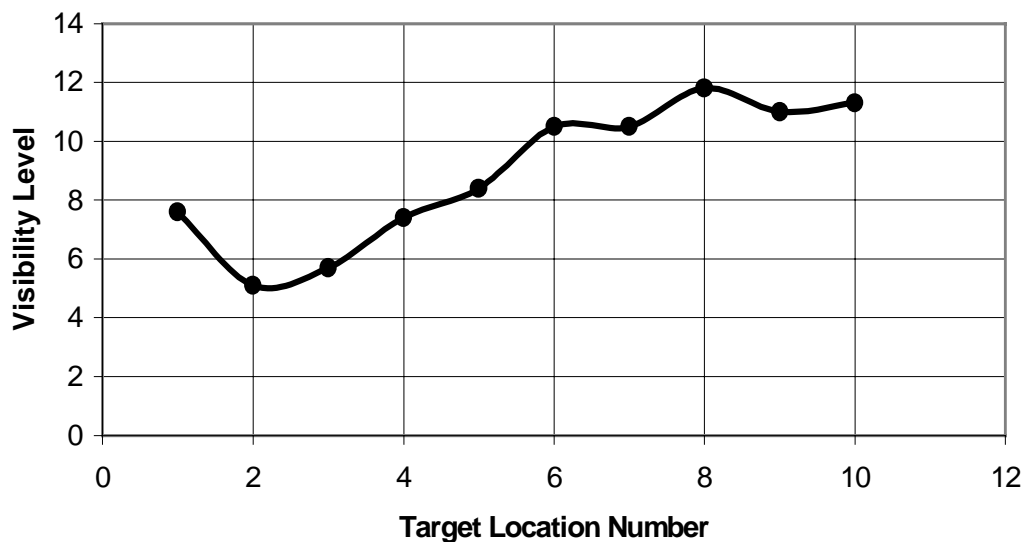
Figure 7 Theoretical visibility distribution

Figure 8 Experimental visibility distribution.

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5. Conclusion

The Keck's program calculates the theoretical visibility distribution by assuming ideal conditions on the roadway. However, installation of poles and luminaires and variations in vertical angel of the pole, rotation and tilt angel of the luminaires, and variations in height and roadway surfaces do not satisfy the ideal conditions. Additionally, environment conditions, the lighting system due to dirty luminaires lenses, and lamp lifetime nonlinearities effect the visibility. The program presented in this paper, it calculates visibility distribution on the roadway by using experimental data. The theoretical and experimental visibility distributions show good agreement dynamically.

Consequently, the presented experimental method may be use to analyse visibility distribution of roadway lighting during the lifetime of the roadway lighting.

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