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Louvers design for LED displays for sunny days

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Abstract

The use of louvers attached to variable information display needs to be optimized taking into account different intrinsic and extrinsic parameters. The analysis of the performance of the display–louvers system takes into account the location, orientation, and daily and seasonal variations. The observation of the system is divided depending on the distance of observation. The far distance vision performance use the background luminance. The medium distance performance needs the use of the Contrast Sensitivity Function of the eye.

Keywords: LED; Display; Panel; Louvers; Road signal

1. Introduction

The use of the Light Emitting Diodes (LED) as the light source in variable display technologies has been established, so far, as a very reliable and efficient light source for large displays. Its use has been spread for different market niches and applications: advertising, signalling information, safety and security applications, etc. Among these applications we are interested in their use for traffic signals and variable information displays in highway traffic control. The growing number of vehicles circulating in roads and highways require more flexible traffic patterns in roads. This flexibility usually improves the efficiency of the traffic but it should maintain the strict safety standards of the road. Then, variable information displays play an important role to fulfil the desired objectives. This is the reason why we may find a large amount of contributions and normative about the implementation of more efficient and reliable variable information displays [1–6]. Within this field of display technologies, this paper analyzes the optimum use of passive elements for improving the performance and readability of the variable information display for traffic control applications (Fig. 1).

Louvers in displays are typically used to avoid the reduction of the contrast as a consequence of direct sun light incidence. They are cheap, easily installed and maintained, and work quite efficiently. However, the appropriate choice of its parameters has to be adapted to the different locations and display geometry. If not, its performance could be compromised and its potential advantages may not be fully obtained. Then, a detailed analysis of the interaction of the shaded and non-shaded zones produced by the louvers on the display board has to include several intrinsic and extrinsic parameters.

This paper is organized as follows. Section 2 describes the most important parameters that should be taken into account for the proper modelling and design of the display–louver element. The different conditions for the observation of the display as a function of the visual regime of the observer are analyzed in two cases: far, and medium distance conditions in Section 3. Near distance observation is not analyzed because of its irrelevance in the traffic control application. The analysis of the far distance observation is made as a function of the sun position that varies along the day and along the year. A human perception model is included to obtain the luminance map in the med-

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Fig. 1. Variable information display in a high-way toll plaza.

ium distance conditions [7,8]. Finally, Section 4 summarizes the main conclusions of the paper.

2. Design parameterization of the display–louver elements

The basic parameters of an optimum louver–display design can be divided in two different categories:

Intrinsic: They account for the characteristics, geometry, and arrangement of the display and louvers. These parameters can be itemized as follows:

- Geometry configuration of the LED board: horizontal and vertical distances between pixels, and between LEDs inside the pixel.
- Geometry and arrangement of the louvers: horizontal and vertical gaps, slope angle.
- Geometry arrangement of the display: height, position, angular orientation.
- Optical properties: LED intensity and colour, and surface reflectance for the display and louvers.

Extrinsic: They describe the geometry and arrangement of the display with respect to the geographic situation and environmental conditions. We may describe the following parameters:

- Geometric parameters for the observation of the display: observation distance, lateral deviation, and angular alignment.
- Hours of operation weighted with some parameters describing the importance of the displayed message.
- Environmental conditions parameterized in external radiation, background luminance.
- Technical and economic restrictions.

Taking into account all previous parameters we can develop a model to study in each case, which will be best solution. In this paper, we have focused our attention on the analysis of the sun location as a function of time along the year. The distance of observation has been also taken into account to properly understand the perception of the display–louver system.

3. Modelling of the performance as a function of the observation distance

Taking into account these previous parameters, the perceived icon or messages from the display will change with both distance and time. Then, we should model a given situation including the effect of the intrinsic and extrinsic parameters on the performance of the display. This subsection has been divided in terms of the different observation conditions parameterized by the vision regime that applies for each case. Section 3.1 is devoted to the case of far vision. In this situation the observer integrates the shadows projected on the signal and the display is seen as a background having uniform luminance. The eye does not accommodate and the correct visualization depends on the angular size subtended by the display. Section 3.2 deals with the conditions that happen in a medium distance observation. The observer sees a luminous LED signal having a patterned shadow background. In this case the evaluation of the contrast needs the modelling of the atmospheric attenuation and the observer Contrast Sensitivity Function, that measure, at a psychophysical level, the response of the human visual system to a sinusoidal pattern as a function of the contrast and the spatial frequency of the pattern.

When the observer can resolve the individual LEDs within a pixel we are in the near vision distance of the display. In this case the treatment is slightly different and it does not correspond with the typical situation that occurs in a regular traffic situation. Some previous works to model this situation have been done in the past [10]. This configuration is used to make a proper design of the pixel unit.

The optimization of the design and its validation using both simulation and field test needs a pre-design stage. In the pre-design we need to define all the material, geometrical, optical, and radiometric characteristics of the display. A given solution, working properly at a specific location and time can perform poorly in a different place or moment. Then, it is necessary to trade some optimum results for an overall good behaviour in most of the locations at the most of the times.

3.1. Far distance vision

In this situation the observer integrates all the background illuminance and cannot distinguish different illumination areas against the background. The standard human observed having a visual acuity of 1 may resolve objects with a $1'$ of angular extent. This will be the maximum angular separation distinguishable. The minimum distance for far vision will depend on the extension of the largest area of constant luminance. For a display–louver system, we may see shaded and no-shaded areas. By evaluating the size of these areas we could calculate the minimum distance for a proper observation of the display. However, this calculation depends on the sun location that changes along the day and with the seasons.

In a simplified example we have considered only the distance between consecutive louvers, that we name as *df*. This distance can be obtained under the maximum angular resolution of 1′ and gives a distance

$$df = dl/\tan(1/60), \quad (1)$$

where *dl* is the distance between louvers as shown in Fig. 2.

The background luminance L_B will be given in this case by the average luminance. If we have a grid with vertical and horizontal visor we can write

$$L_B = [L1(dv \cdot sh + dh(sv - dv)) + L2(sv - dv)(sh - dh)]/sv \cdot sh, \quad (2)$$

where $L1$ is the luminance of the non-shaded areas, and $L2$ is the luminance of the shaded areas. *sv* is the vertical separation between louvers and *sh* is the horizontal distance between louvers, *dv* vertical length of the shadow and *dh* is the horizontal length of the shadow as shown in Fig. 3.

In this example we will use the geometric parameters given in Table 1. These parameters closely correspond with an actual design of display–louvers elements. As we previously pointed out, the ratio between the shaded and non-shaded areas changes along the day and the year. Taking into account this variation we have evaluated the luminance of a display–louver system as a function of time. The orientation of the system is looking South and the geographic location is Madrid, Spain. We have not considered the atmospheric attenuation, and we have used a basic model for diffuse illuminance [9].

Fig. 4 shows the luminance of the display–louver system for a solar height angle of 55° and an azimuth of 20° when the LEDs are turned "off" and "on". For both cases it is possible to see two different areas corresponding with the

Table 1
Geometric and reflectance parameters of the display and louvers

Board width	300 mm
Board height	400 mm
Louver length	30 mm
Louver vertical distance	57 mm
Louver horizontal distance	177 mm
Panel reflectance	0.3

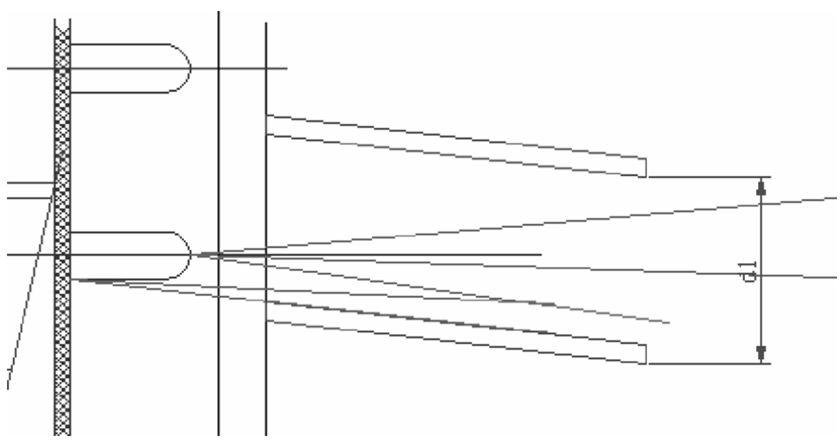

Fig. 2. Geometrical arrangement of a LED panel with louvers.

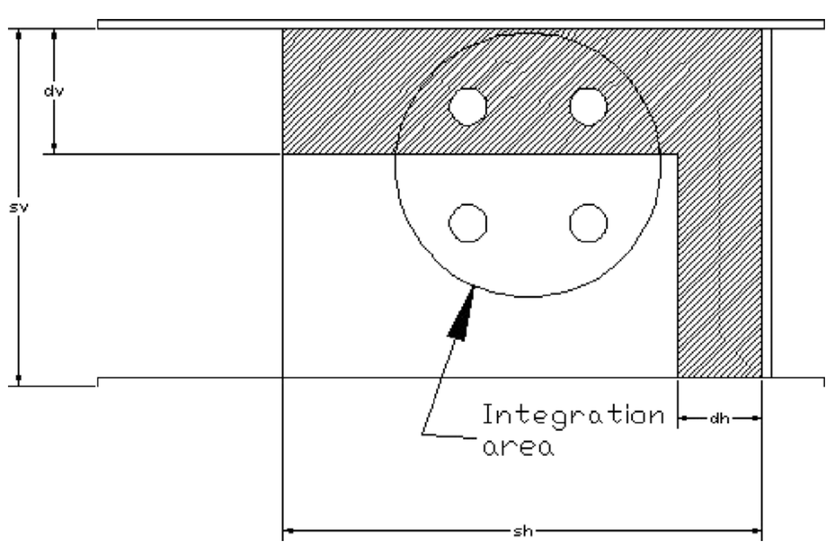

Fig. 3. Background shadow parameters and integration zone.

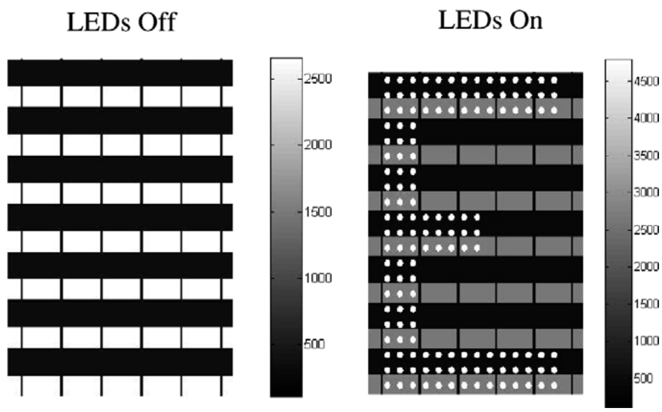

Fig. 4. Luminance distribution for the display–louver system having the parameters given in Table 1. The distributions are for the LED ‘‘on’’ and ‘‘off’’.

shaded and non-shaded regions on the display. The shaded areas have a luminance of about 500 cd/m^2 meanwhile the non-shaded areas show a luminance of about 2500 cd/m^2. Besides, the bright locations in the system when the LEDs are ‘‘on’’ correspond with the luminance of the emitters: 4500 cd/m^2.

As far as the sun moves daily and seasonally we need to calculate the luminance map for a specific period of time. On the top-left of Fig. 5 we have shown the change in luminance along the 1st of January for the different portions of the display: shaded areas (dotted line), non-shaded areas (dashed line). The solid line represents the background luminance given by Eq. (2). The contrast, defined as the ratio between the LED luminance and the background luminance, is plotted in the top-right plot of Fig. 5. The contrast reaches a maximum value when the sun is not present. Therefore, this graphics shows the values of the contrast for the central portion of the day. The bottom-left of Fig. 5 shows the same three luminances for the display–louvers system along the 30th of May. We may see that different contributions to the background luminance have changed with respect to the January 1st situation. The contrast variation for May 30th is also represented in the bottom-right plot of Fig. 5. Now, the Sun is present longer than in January 1st, making the contrast larger and lasting longer. When the calculation is made for the whole year it is possible to determine if the display–louver system complies with the requirements of presenting a minimum contrast. This is typically done by minimizing the background luminance, L_B, for a given value of the LED luminance. The daily and seasonal evolution of L_B is plotted in two portions (January–March and April–July) in Fig. 6 for half a year since January 1st to July 2nd (the graphic is symmetric for the other half being the center of symmetry located at the summer solstice, June 21st).

3.2. Medium distance vision

In this section we are going to consider a more complex model to analyze the image perceived by the observer when

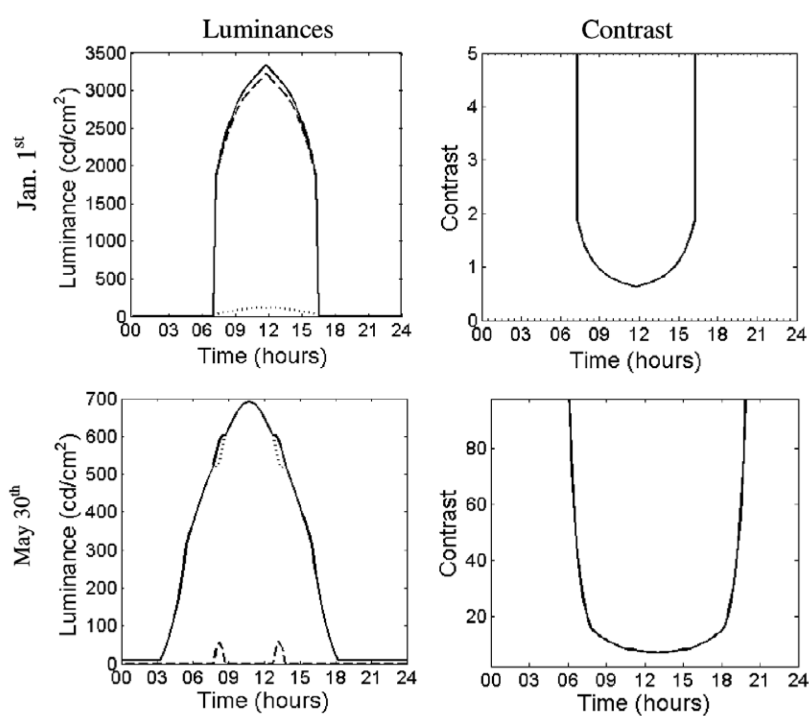

Fig. 5. The left column shows the temporal evolution along the day of the contributions to the background luminance expressed in Eq. (2). The contribution from the shaded zones (dotted line) and the non-shaded zones (dashed line) combine together to the background luminance (solid line). The right column is plotting the contract along the day. The row on the top is for January 1st and the bottom is for the May 30th.

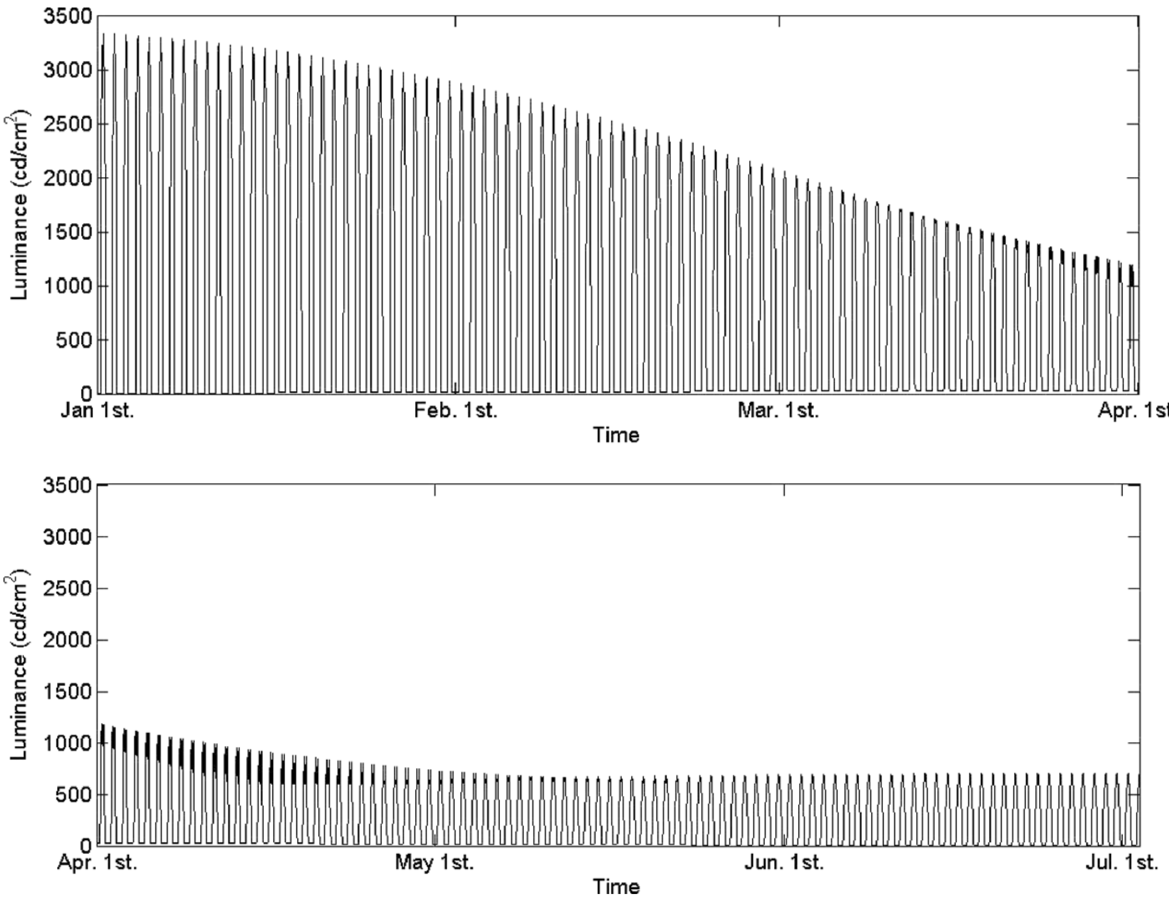

Fig. 6. Half-year evolution of the background luminance (Eq. (2)) divided in two parts: January–March (top) and April–July (bottom). The evolution is symmetric with respect to the summer, or winter solstice.

looking at a display–louvers system. When an icon or character is presented in the display by driving "on" and "off" the pixels of the displays, the perceived contrast is determined by the spatial frequency content of the object [7,8]. On the other hand, the observer perception is modulated by the Contrast Sensitivity Function (CSF) of the eye. The evaluation of the perceived image is done as follows. First, we calculate the spatial frequency spectra of the object by using the Fourier transform of the luminance distribution of the object that we write as

$$M(f_x, f_y) = \mathrm{TF}[M(x, y)], \tag{3}$$

where M is the luminance spatial distribution, and f_x, f_y are the spatial frequencies along the x- and y-axis, respectively. This spectrum is processed by the observer using the CSF. Then, spatial frequency content is modified in the following form,

$$\mathrm{IM}(f_x, f_y) = M(f_x, f_y)\mathrm{CSF}(f_x, f_y), \tag{4}$$

where the CSF acts as a linear filter. Then, the final perceived image can be obtained by applying the inverse Fourier transformed to this modified spectrum,

$$\mathrm{IM}(x, y) = \mathrm{TF}^{-1}[\mathrm{IM}(f_x, f_y)], \tag{5}$$

where $\mathrm{IM}(x, y)$ is considered as the perceived image by the human visual system.

In the following analysis we have applied this procedure to the display–louvers system shown in Fig. 4. The location of the system is the same as in Section 3.1. The luminance calculation is made for midday. The display is showing the letter "E".

Fig. 7 shows the perceived image when the panel is seen from 50, 25, and 10 m. The perceived image of the letter "E" is shown along with a vertical cross-section of the normalized luminance spatial variation. We may check that the difference between high-luminance and low-luminance areas increases as we move closer to the display–louvers system. This difference is directly related with the contrast of the image. Therefore, we may conclude that the contrast increases as we move closer to the display–louvers system.

4. Conclusions

In this paper, we have analyzed the performance of display–louvers system as a variable information element for its use in traffic signalling. The treatment for the far distance conditions is made by calculating the luminance of the whole system composed of different portions of shaded and non-shaded regions. For a given location and orientation of the display–louvers system, it shows a

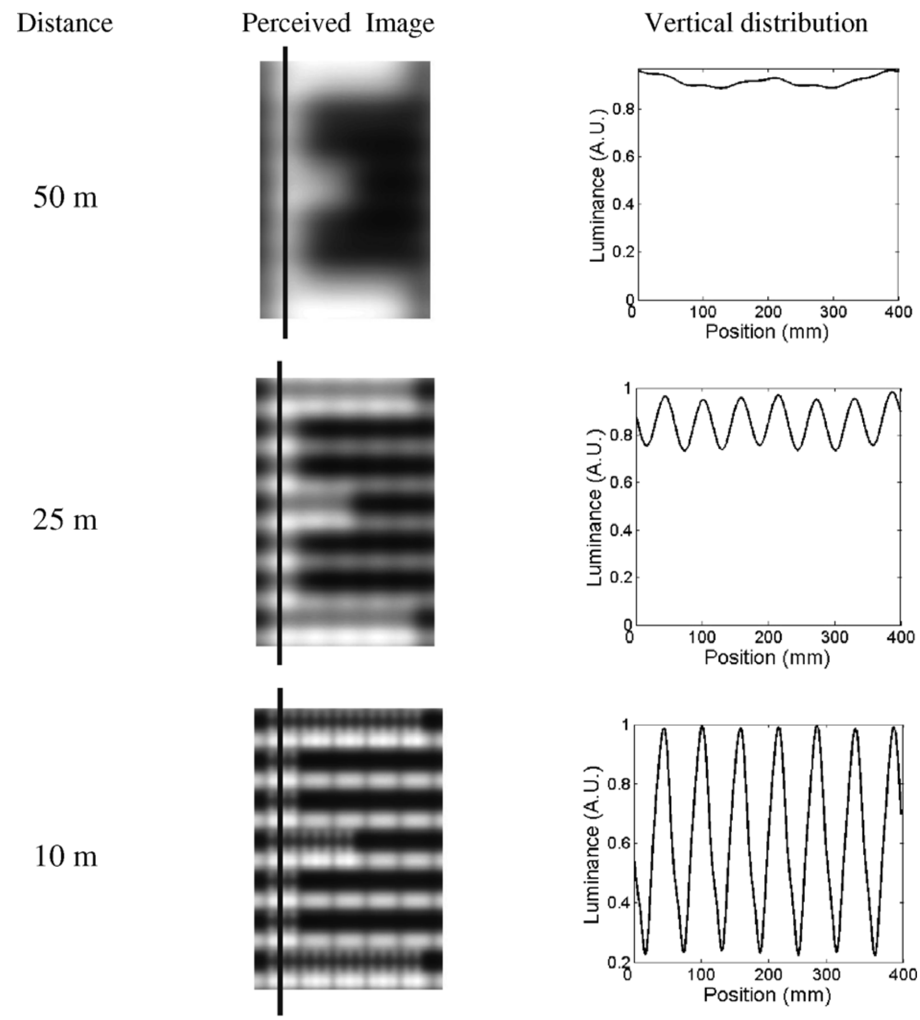

Fig. 7. Representation of the perceived image by a human observer when the symbol is presented in the display–louvers system and it is located at 50 m (top), 25 m (middle), and 10 m (bottom). The right column is a vertical cross-section of the luminance spatial distribution. This section is made along the vertical line plotted in the perceived image.

variable performance along the day and the year because of the daily and seasonal sun movement. When the observer approaches the display–louver system he enters into the medium distance vision. This case is treated in a different way because now the observer is able to distinguish the pixels and perceive an image. This image is calculated by taking into account the CSF of the human visual system.

By using the proposed techniques it is possible to compute the performance of the display–louver configuration at a given location along an extended period of time. Some refinements of the model can be made to include atmospheric propagation for different weather conditions. However, the method proposed here can be of use for checking the capabilities of a combination of intrinsic and extrinsic parameters of the overall design.

A complete design should make use of a merit function that weights the different daily, seasonal performances according to the desired use of the system for a geographic location, orientation, and observer positioning.

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