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Lighting control system based on digital camera for energy saving in shop windows

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ABSTRACT

Shop window lighting usually represents a meaningful quantity in the lighting consumption of a shop because the large amount of installed power and its high number of running hours. Dimming of lighting can improve its energy efficiency, however, conventional systems, as photocell detectors, are difficult to be used. Besides, the usual control objective of daylight harvesting cannot be applied in this context because here the main objective is to maintain the attractiveness on shop window.

In this paper, a control system for shop window lighting is proposed. In this system, a digital camera as a luminance meter has been used. Furthermore, the main objective of the controller is to keep constant the contrast of the shop window interior with respect to its surroundings.

The proposed control has been tested in a shop window prototype where real working conditions have been simulated.

1. Introduction

Shop windows are designed to attract the attention of passers-by, because they often represent the first contact with the products of a shop. In this task lighting plays an important role. The lighting method usually preferred is the accent lighting due to design esthetics and to emphasize the perceived contrast [1,2]. As a result, the achieved illuminance values can be as high as 5000 lx during nighttime and 10,000 during daytime. [3]. Certain studies show that a higher illuminance level implies that more passers-by are attracted by the shop windows [2]. However, in order to make shop windows attractive, contrast is more important than illuminance levels [4]. A recommend value for luminance ratio between the illuminated object and the surrounding area is 3:1, although this ratio can reach values from 10:1 to 30:1 [5].

The lighting system of shop windows is usually formed by sets of halogen lamps with a power around 100 W per unit that remain on at least 15 h per day [6]. Although there are other lighting technologies much more efficient [7], designers are usually reluctant to use them due to the well-known properties of incandescent lighting. As a consequence, the lighting of shop window could represent a significant amount of the electric energy consumed by a shop.

As mentioned above, lighting requirements can be reduced during night time, due to the fact that contrast with surroundings can be more easily achieved. So, lights can be dimmed by means a closed loop dimming system that gradually diminishes their amount of light when the light in the exterior falls. Typically photosensors are used to light control [8–11]. Nevertheless, their use is nontrivial because their response depends on reflectance changes in room surfaces, the position of the sensor relative to daylight apertures...; as a result, it could be difficult to ensure an enough correlation with the daylight levels [5,12,13]. A digital camera can be used as a substitute of photosensors to overcome their usual problems [13,14]. However, it must be calibrated in order to measure the luminance of a determinated area.

The common control practice in lighting is to keep the illuminance or luminance level constant against daylight variations [12,13,15]. In this way, the achieved lighting harvesting implies a reduction in the energy consumption of lighting system. Although this strategy is valid for task places, it cannot be used in shop windows because here the objective is to maintain the contrast while keeping an acceptable luminance level.

In this paper, a closed loop dimming system for shop windows is presented. This system uses a digital camera as a luminance meter. The control is focused in keeping constant the contrast of the shop

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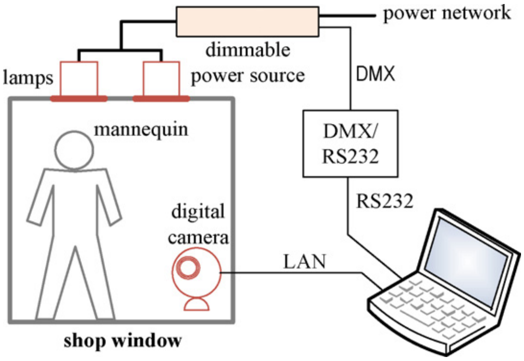

Fig. 1. Proposed lighting system for shop windows.

window content with respect to its surroundings. The control system has been tested in a scaled prototype of a shop window.

The work presented in this paper is part of the Ecoefficient Store Project. It is included in the Inditex Global Strategy for Sustainability and Innovation. Its aim is to extend the sustainability criteria to their shop windows, which will allow us to reduce the environmental impact at all of the stores which belong to the different brands of the Inditex Group.

2. Lighting system for shop windows

The proposed lighting system is composed by (see Fig. 1):

- A set of lamps with a dimmable power source.
- A digital camera.
- A PLC or PC where the control algorithm is implemented.

The proposed setup works in the following way. The digital camera takes images from the interior of the shop. From these images, the luminance of a specified region of interest (ROI) is obtained, and the contribution of exterior light is estimated. According to these parameters, the lamp light is controlled in order to try to maintain the contrast of shop window content with respect to its surrounding areas.

The tasks of the control system can be divided in (see Fig. 2):

- Calibration: the camera response and the response of lighting system are obtained. This is done occasionally, e.g., it must be done every time that changes the decoration of the shop window.
- Contrast control:the dimming level is controlled in order to keep the contrast near or, preferably, slightly above from its objective value.

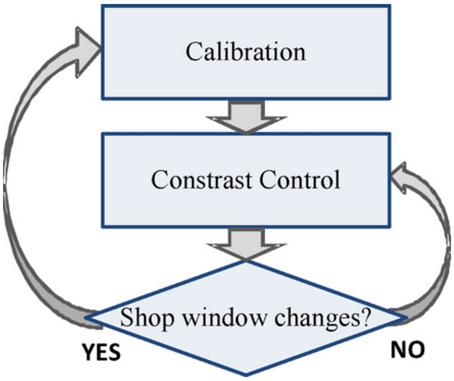

Fig. 2. Control system tasks.

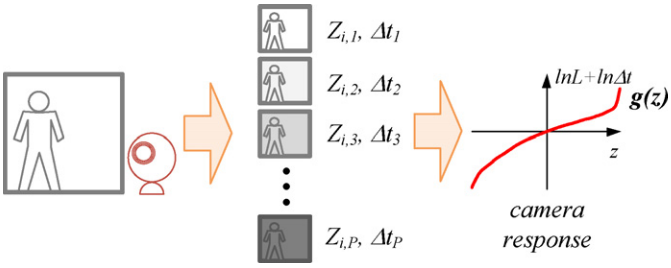

Fig. 3. Procedure to obtain the camera response $g(z)$.

In the following paragraphs, the procedure to calibrate the system and the proposed control algorithm are presented.

2.1. Calibration: digital camera as a relative luminance meter

Digital cameras can be used to measure the luminance of a scene so they can be included in a lighting control system [13,14,16]. For this purpose, the camera must be previously analyzed in order to obtain its response, i.e., the relationship between pixel and luminance values [5,17,18]. For this, it has been used a technique called High Dynamic Range (HDR) consisting in taking images at multiple exposure durations, see Fig. 3, which allows to capture a wide range of luminance values within a scene [13,14,18,19,20]. With this method, the average relative luminance relative luminance inside a selected ROI can be obtained (see Appendix A for details).

2.2. Calibration: response of lighting system

After the relative luminance values are obtained, it must be calculated the response of the lighting system as the relation between the average relative luminance provoked by shop window lamps and the dimming level. This relation is expected to be linear, but their parameter depends on shop window elements (e.g. textures, lamps distribution. . .), as a consequence, it must be obtained from measurements. From experiments done with a low contribution of exterior light inside the shop window, the following relationship can be obtained:

$$L_l = b_0 + b_1 P \tag{1}$$

where L_l is the average relative luminance in the ROI provoked by the shop window lamps, P is the dimming level (where 1 mean full power and 0 implies that lamps are switched off) and b_0 and b_1 are the constants of the linear relationship. When a value distinct to zero for parameter b_0 is obtained, this is usually due to some exterior light or the dark field effect, so this term is usually neglected ($b_0 \approx 0$) [21].

2.3. Control algorithm

The objective of the proposed shop window lighting control is to maintain into an acceptable range of values the contrast of a selected ROI with respect to the shop window surroundings. According to this, a contrast definition based on Weber definition of contrast and where the exterior light contribution has been considered [22]:

$$C = \frac{L_{av} - L_x}{L_x} \tag{2}$$

where L_{av} is the relative average luminance measured in the ROI, see Eq. (19) in Appendix A, and L_x is the relative luminance related to light in the exterior of shop window.

The light in the outside of shop window cannot be measured with a digital camera installed in the shop window interior. As a

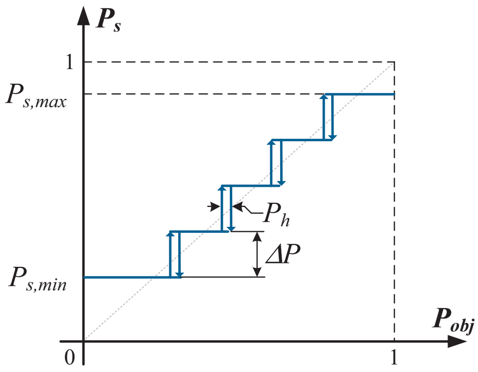

Fig. 4. Relationship between objective and control dimming levels.

consequence, it had to be estimated from relative luminance values taken from the shop window interior images. For this purpose, the light coming from the outside is supposed to be uniform and diffuse and, as a consequence, the superposition principle can be applied [23,24]. Thereby the relative luminance measured in the ROI can be decomposed as the sum of the contributions of the light coming from exterior and from shop window lamps. So, the value of L_x can be obtained as the difference between the measured relative luminance and the luminance to be expected according to the dimming level:

$$L_x = L_{av} - L_l = L_{av} - b_1 P \tag{3}$$

Consequently, for a given objective of contrast C_{obj}, the objective dimming level P_{obj} can be established using [24]:

$$P_{obj} = \frac{C_{obj}}{b_1} L_x \tag{4}$$

In order to avoid sudden or constant changes inside the illumination level of shop window and to try to keep the contrast slightly higher than its objective, the control dimming level P_s to be sent to the lighting system is defined from the objective dimming level P_{obj} by means of the stepped function with hysteresis shown in Fig. 4 [5]. The parameters for that function are:

- $P_{s,min}$ is the minimum value for the control dimming level (e.g. $P_{s,min}$ equals to 0.5 or 50%). This value guarantees that, under low exterior lighting conditions, the shop window keeps an acceptable luminance level.
- $P_{s,max}$ is the maximum value for the control dimming level (e.g. $P_{s,max}$ equals to 1 or 100%).
- ΔP is the height of each step.
- P_h the width of threshold.

The resulting control scheme can be seen in Fig. 5 where the steps needed and the parameters involved for obtaining the dimming setpoint are shown.

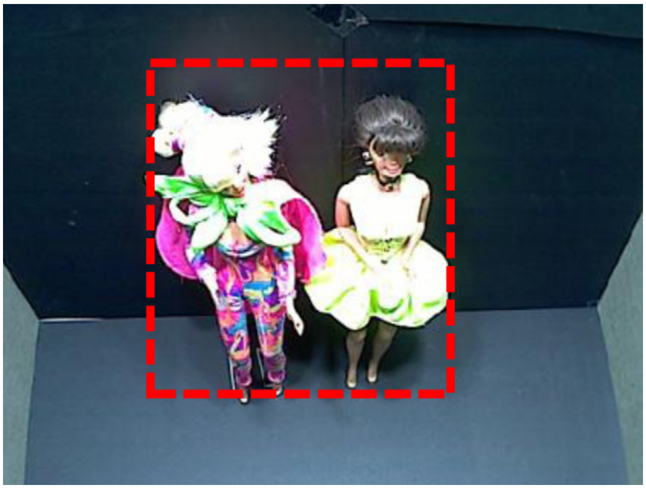

Fig. 6. Digital image and ROI (dashed rectangle).

Table 1
ROI limits in pixels (image size 640 × 480).

X range	150	450
Y range	90	420

3. Test setup and results

3.1. Shop window prototype

The proposed control scheme has been tested in a shop window prototype whose main elements are:

- Shop window container whose dimensions are: 440 mm × 563 mm × 795 mm.
- LED lamps (four units of 12 W) with a dimmable power source controlled via DMX. The lamps are installed in the upper front of shop window.
- Digital camera, webcam with LAN connection.
- PC where the control system is installed.

The digital camera used must at least allow the manual control of the exposure parameters: exposure duration (or shutter speed), aperture (or f-stop) and gain (or ISO). In this prototype, a low cost Webcam with that capability has been chosen.

3.2. Calibration: camera response and lighting system response

The first step to test the proposed control system is to define ROI, as shown in Fig. 6 and in Table 1. Once the ROI is established all the obtained luminance values are referred to that area.

The following step is the camera calibration. For this purpose, a set of images at several exposure durations (1/4, 1/8, 1/16, 1/32 1/64, 1/128, 1/256 and 1/512 s) have been taken (see Fig. 7). For the calculation of $g(z)$, the ROI has been sampled to obtain $N = 1500$ equally spaced pixel values (the ROI has $N_{ROI} = 99{,}000$ pixels). The resulting transfer function $g(z)$ is shown in Fig. 8.

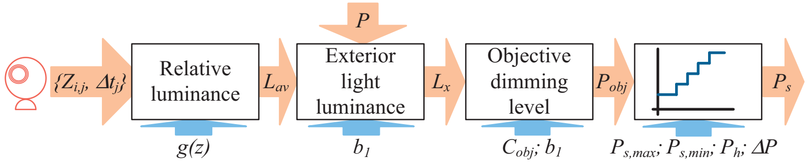

Fig. 5. The control scheme.

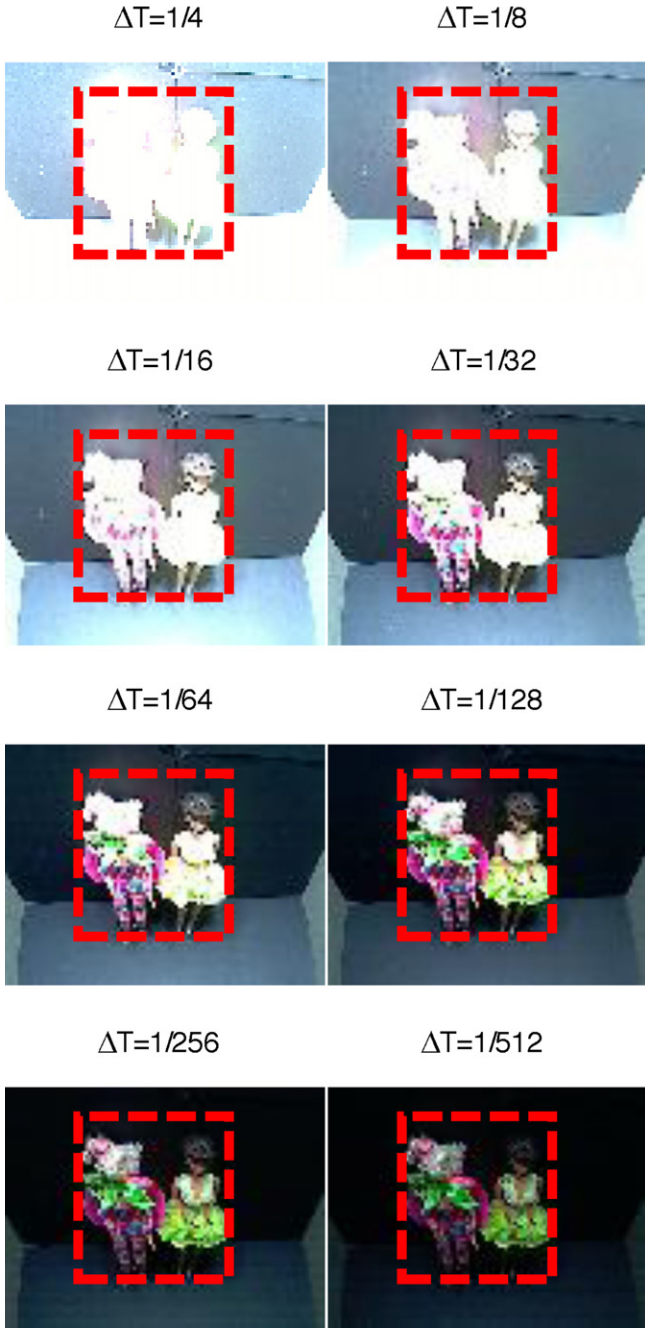

Fig. 7. Set of images for camera calibration.

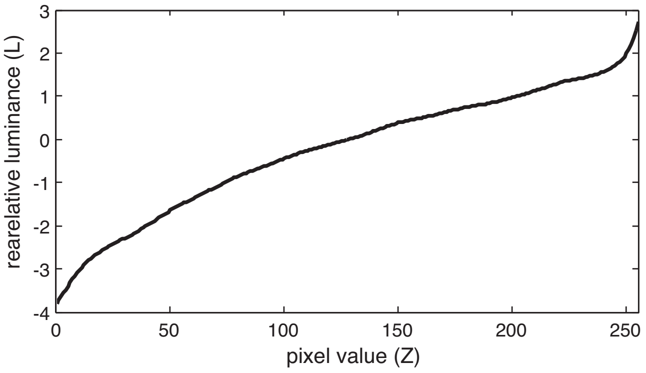

Fig. 8. Digital camera response (*g*).

Although LEDs lamps have been used for the prototype, the robustness of the proposed calibration process when lamps with different light spectra are used has been tested in Appendix B.

Once the relationship $g(z)$ between pixel values and relative luminance is obtained, the lighting system response is obtained by illuminating the interior of shop window at different dimming levels (from 0.1 to 1). This step has been done under low, but not zero, exterior light conditions in order to simulate real life conditions. As a result, (see Fig. 9), a linear relationship, with a coefficient of correlation (R^2) value greater than 0.995, between the dimming level and the average relative luminance is obtained ($b_0 = 0.14$ and $b_1 = 31.06$).

Table 2
Control lighting setpoints parameters.

Maximum dimming level $P_{s,max}$	1
Minimum dimming level $P_{s,min}$	0.5
Step height ΔP	0.1
Threshold width P_h	0.02

3.3. Contrast control

The control proposed for the lighting system is tested using an objective contrast (C_{obj}) equals to 1, that means that the objective is to get a relative luminance value (L_{av}) equals to twice the exterior luminance ($L_{av} = 2L_x$) or to get a contribution of lighting system (L_l) equals to the exterior luminance ($L_l = L_x$). The parameters for the control function shown in Fig. 4 are shown in Table 2, and they have calculated in order to maintain the achieved contrast above the objective contrast.

The response of the proposed system under different daylight conditions (see illuminance values in Fig. 10) has been tested. These conditions have been selected to be similar to those in a real retail store (see Appendix C). It must be taken into account that the shop window prototype has been installed inside a laboratory whose windows are orientated to the west; that implies that the maximum exterior light influence occurs at the afternoon hours.

The relative luminance values (L_{av}, L_l and L_x) obtained during the test are represented in Fig. 11. The resulting objective dimming level (P_{obj}) values and control dimming level (P_s) values are shown Fig. 12.

The achieved values of contrast are shown in Fig. 13. As can be seen, the contrast tends to be slightly higher than its objective when exterior light is present. When exterior light contribution is very low, the contrast shows the highest values because the lighting system has a minimum dimming level of 50%.

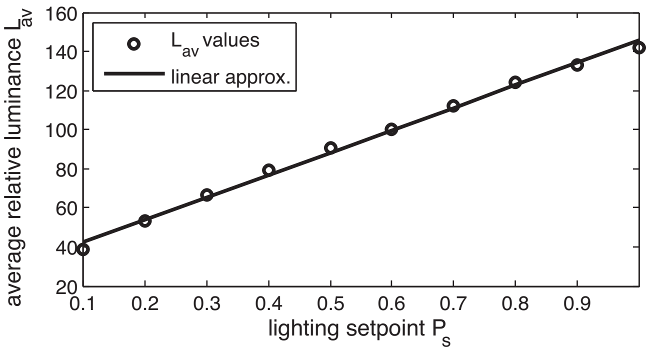

Fig. 9. Lighting system response.

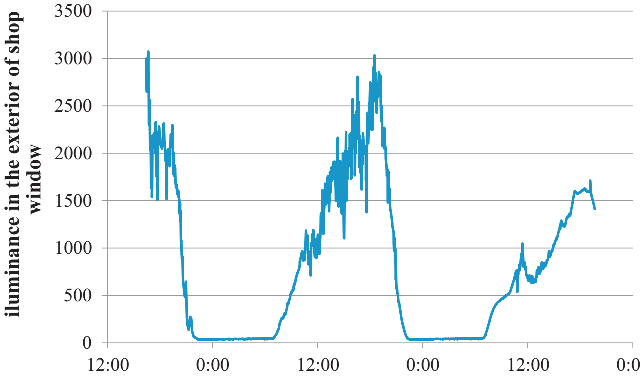

Fig. 10. Illuminance values measured in lux at the exterior of the shop window prototype.

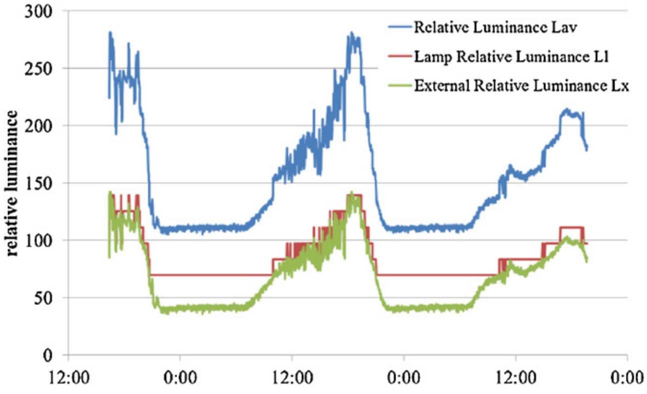

Fig. 11. Relative luminance values.

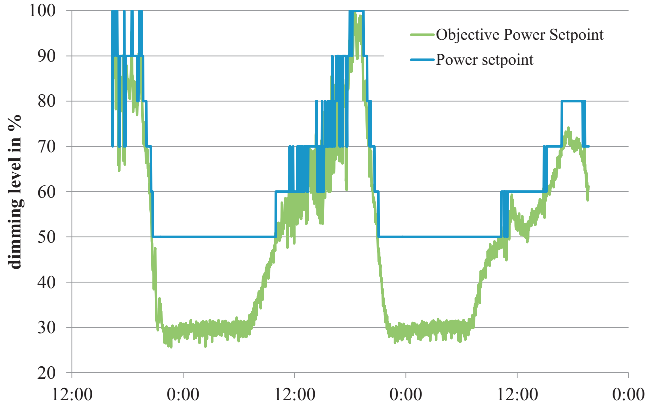

Fig. 12. Dimming level values in %.

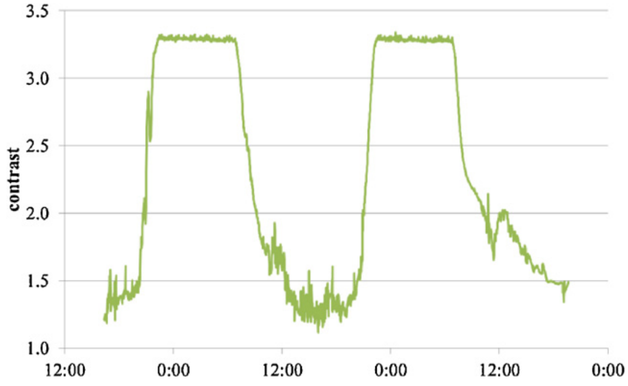

Fig. 13. Contrast values.

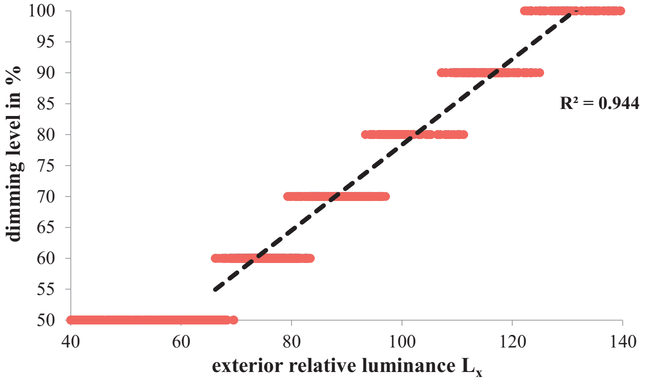

Fig. 14. Dimming level vs. exterior relative luminance.

The achieved dimming level values under different levels of exterior relative luminance are shown in Fig. 14. As expected according to (4), the obtained relationship tends to be linear.

4. Discussion

Lighting energy consumption in nonfood retail stores accounts for the 26–50% of their total energy demand [25,26]. In this context, different standards and regulations establish limits for store lighting in terms of power density, minimum lighting efficiency... [27]. Nevertheless, accent lighting, as that which is generally installed in shop windows, is usually considered apart in such standards, and their limits are less restrictive than those for general lighting. However, shop window lighting is being included in the energy efficiency strategies of retailers like Inditex [28] or even in local city proposal of regulaments [29].

From the results of the tests in III.C, the energy saving estimations shown in Table 3 can be obtained. As a conclusion, the energy saving in a shop window (typ. 13.5–15 running hours per day [7]) during a sunny day could be roughly a 30%. Moreover, when a two level strategy is implemented, e.g. by using a timer to dim the lamps at a 50% during night hours, the energy saved is approx. a 10% for 13.5 shop window running hours.

In order to estimate the impact of implementing the proposed control in the energy consumption of retail stores, it would be necessary to know the consumption of the different lighting uses. Nevertheless, that kind of information is not generally publicly available. So, for this purpose, data from a real retail store located at Vigo (Spain) have been used (see Fig. 15). The store has a shop window of 5.5 m long facing to the street with a lighting power of 2100 W (387 W/m) and 13.5 running hours (from 10:00 to 23:30). These data are close to those given by Simeonova et al. [7]. In this case, the energy consumed by the shop window represents roughly a 5% of the total amount of the energy consumed by the overall store lighting. Using the energy saving value obtained during the tests (see Table 3), which is approximately a 30%, this would imply 3116 kWh or 1235 kg of CO_2 [30] saved per year.

Finally, when the proposed system is compared to a closed loop dimming control based in light sensors or photosensors, it can be achieved similar savings. However, with the system proposed the

Table 3
Estimation of energy savings.

Running hours	Energy saved (%)
24 h/day	40
15 h/day (e.g. 9:00–24:00)	32
13.5 h/day (e.g. 9:30–23:00)	30

Fig. 15. Retail shop window orientation in a street of Vigo (Spain).

typical drawbacks [5] related to their use can be overcome, for example:

- The position of the photosensor with respect to the window or windows is critical to ensure a good correlation between the exterior light and the signal of the sensor.
- The commissioning for dimming controls based on light sensors system typically involves a calibration process using luminance or illuminance meters.
- The use of the light sensor makes impossible the definition of the relevant zone inside the shop window (ROI) as a target for control of lighting parameters.
- The changes in reflectance surfaces inside the ROI can affect to its lighting parameters; these changes are properly taken into account with the system proposed.

5. Conclusions

In this paper, a control scheme for the lighting system of shop windows is proposed. The main characteristics of the proposed system are:

- A low cost digital camera, a webcam, is used as a relative luminance meter.
- It is defined a ROI in the images of shop window interior where the lighting parameters are obtained.
- A calibration procedure based on HDR analysis techniques is used to obtain the digital camera response that allows relating pixel values and relative luminance values.
- The contribution of interior lighting to the ROI luminance level for a given dimming level is calculated.
- The contribution of exterior light to the relative luminance is estimated from average luminance inside the ROI and the actual dimming level.
- The control dimming level is defined from an objective contrast.

As a consequence, the proposed system estimates the level of exterior light and varies the dimming level trying to keep the contrast in a given value.

This control system has been tested on a prototype where the real working conditions of a shop window are simulated. Results show that by mean this algorithm the contrast can be maintained fairly constant against exterior light (e.g. daylight) variations.

By mean the proposed approach, the energy efficiency of lighting of shop windows can be significantly increased. In fact, from estimations using data from a real retail store, the savings could be more than a 30%.

The main advantages of the proposed approach are the establishment of an objective based on contrast using the estimation of exterior light. Furthermore, the main drawbacks of using control systems based on photosensors can be avoided.

Acknowledgement

This work has been supported by Antonio Álvarez Sánchez, from the Environmental Department at Inditex.

Appendix A. Procedure to obtain the relative luminance of a ROI

(i) Obtention of digital camera response

The response of a digital camera for a set of digital images taken at a constant lens aperture (*f-stop*) and sensitivity (*ISO*), can be written means the expression [17,19,20,31]:

$$Z_{ij} = f(L_i \Delta t_j) \tag{5}$$

where i is an index for a position in a digital image, j indexes over exposure durations Δt_j in s, Z_{ij} represent the pixel values within a defined ROI and, finally, L_i is the luminance in cd/m^2. The pixel values of images are usually obtained from an A/D conversion with 8 bits, [31] so their values are integers that range from 0 to 255.

In order to obtain the response of the digital camera, Eq. (5) can be rewritten as [19,20]:

$$g(Z_{ij}) = \ln(f^{-1}(Z_{ij})) = \ln L_i + \ln \Delta t_j \tag{6}$$

As a result, using the HDR technique (see Fig. 3), the response function $g(z)$ can be calculated minimizing the following quadratic objective function, proposed by Devebec and Malik in [19]:

$$\vartheta = \sum_{i=1}^{N}\sum_{j=1}^{P} w(Z_{ij})[g(Z_{ij}) - \ln L_i - \ln \Delta t_j]^2 + \lambda \sum_{z=Z_{\min}+1}^{z=Z_{\max}-1} w(z)[g''(z)]^2 \tag{7}$$

where

- N is the number of pixels locations considered.
- P is the number of exposure durations.
- λ is a smoothing factor (typ. around 100) to ensure the smoothness of $g(z)$. It affects to the second derivative of g that can be defined by:

$$g^{''}(z) = g''(z-1) - 2g(z) + g(z+1) \tag{8}$$

- $w(z)$ weighting function that gives more weight to the pixel values (z) near the mid range of pixel values than those near to the minimum ($Z_{min} = 0$) and maximum values ($Z_{max} = 255$). It is defined as:

$$w(z) = \begin{cases} z - Z_{\min} & when\, z \leq \frac{1}{2}(Z_{\max} + Z_{\max}) \\ Z_{\max} - z & when\, z > \frac{1}{2}(Z_{\max} + Z_{\max}) \end{cases} \tag{9}$$

The resulting L_i values can be related to real luminance values by means of a constant [18,19], that must be obtained from a set of measurements of luminance values in the scene. However, for the proposed approach it is enough to know the relative luminance values inside the scene. So, an arbitrary factor scale can be established. This is done by using the following relationship:

$$g(Z_{mid}) = g(\tfrac{1}{2}(Z_{\max} + Z_{\min})) = g(125) = 0 \tag{10}$$

(ii) Camera response recovery

As a result, to obtain the camera response $g(z)$ it must be solved an over determinated system formed by $NP + n$ equations, where n is the number of distinct gray values ($n = Z_{max} - Z_{min} + 1$).

In order to reduce the computational effort, instead of using the entire set of pixels values inside the ROI, a reduced set of locations inside the ROI are used. They are selected by sampling techniques, taking into account that the resulting distribution of pixel values must be close to the distribution of pixel values inside the entire ROI. So, equation (can be solved using the following matrix equation:

$$\mathbf{Ax} = \mathbf{b} \tag{11}$$

where

- **b** is a vector whose size is $(NP + n + 1) \times 1$, and it is formed by the following elements are:

$$b[k] = \begin{cases} w(Z_{ij})\Delta t_j & k = ij \leq N \times P \\ 0 & k > N \times P \end{cases} \tag{12}$$

- **A** is an array whose size is $(NP + n + 2) \times (N + n)$, where non-zero values for the first NP rows are defined by:

$$\begin{aligned} \mathbf{A}[k, Z_{ij}] &= w(Z_{ij}) \\ \mathbf{A}[k, Z_{\max} - Z_{ij}] &= w(Z_{ij}) \end{aligned} \tag{13}$$

With $\mathbf{k} = ij$. The non-zero element of $NP + 1$ row is:

$$\mathbf{A}[NP + 1, Z_{mid}] = \mathbf{A}[NP + 1128] = 1 \tag{14}$$

Finally, the non-zero elements for the last n rows of **A** are:

$$\begin{aligned} \mathbf{A}[k, z] &= \lambda w(z + 1) \\ \mathbf{A}[k, z + 1] &= -2\lambda w(z + 1) \\ \mathbf{A}[k, z + 2] &= \lambda w(z + 1) \end{aligned} \tag{15}$$

With $k = NP + 1 + z$ and z ranging from 0 to 255.

- **x** is the vector to be obtained with $n + N$ elements whose values are:

$$\mathbf{x}[k] = \begin{cases} g(z = k - 1) & k \leq n \\ L_i & n < k = i + n \leq n + N \end{cases} \tag{16}$$

Eq. (11) (has been solved using the singular value decomposition (SVD) method.

(iii) Relative luminance calculation

Once the transfer function $g(z)$ is obtained, the relative luminance of each ROI location can be obtained using (6). However, for robustness, it is more convenient to use the weighting function $w(z)$, so, relative luminance values can be obtained from [19]:

$$ln\, L_i = \frac{\sum_{j=1}^{P} w(Z_{ij})[g(Z_{ij}) - \ln \Delta t_j]}{\sum_{j=1}^{P} w(Z_{ij})} \tag{17}$$

As a result, the luminance values are less sensitive to the noise in the digital image and the oversaturated and undersaturated pixel values are neglected.

Finally, the average relative luminance L_{av} of the selected ROI under determined lighting conditions can be obtained using:

$$L_{av} = \frac{1}{N_{ROI}} \sum_{i=1}^{N_{ROI}} L_i \tag{18}$$

where N_{ROI} is the number of pixels inside the ROI.

(iv) Practical considerations about camera response

In the proposed approach, before to obtain the camera response, some considerations have been taken into account:

- The selected ROI must avoid the peripherals areas of the image in order to minimize the impact of the vignetting effect [17,18,31].
- In order to reduce computation time, instead of using the RGB values, the gray scale values Z_g have been used for camera calibration [32]:

$$Z_{g,ij} = 0.299R_{ij} + 0.587G_{ij} + 0.114B_{ij} \tag{19}$$

where R, G and B represent the RGB values of the digital image. As an indicator of goodness of this approximation, it must be noted that the error when the parameter b_0 is calculated is about 7%. The resulting values of this expression have been rounded to integers between 0 (Z_{min}) and 255 (Z_{max}).
- One drawback of HDR technique is its sensitivity to signal noise, especially high in low cost digital cameras, and to misalignment between the images taken at different exposure durations. To overcome these problems and avoid complex alignment algorithms [33] an averaging filter has been applied over the images [32]. The resulting filtered gray pixel values Z are used as input to the camera response calculation:

$$Z_{g,ij} \overset{averaging\, filter}{\longrightarrow} Z_{ij} \tag{20}$$

The resulting values of this process have been rounded to integers between 0 and 255.

Appendix B. Camera calibration with different lamps

It has been tested the behavior of the camera calibration process when lamps with different light spectra are used. The selected technologies were halogen, LED and metal halide lamps. They were installed in the shop window prototype, and the results for the camera calibration process are shown in Fig. 16. The resulting camera response functions for the different technologies are similar, so, the proposed process is supposed to be fairly robust against the use of different lamps technologies or different light sources.

Appendix C. Analysis of illuminance conditions

The illuminance conditions of the tests presented in Section III has been established so as to be similar to the illuminance conditions in the real retail store presented in Section IV. In order to

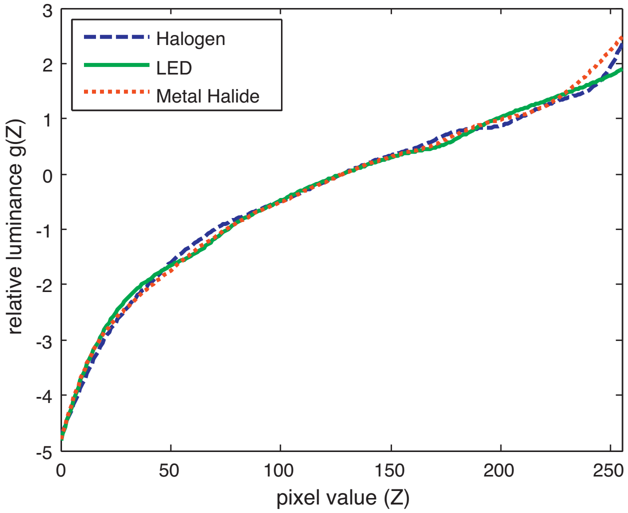

Fig. 16. Digital camera response (g) for different lamps.

compare the illuminance values in the prototype and in the retail store, it must be considered the following ratios:

- K_{av}: ratio between maximum interior illuminance due to the lighting system and the average exterior illuminance.
- K_{max}: ratio between maximum interior illuminance due to the lighting system and the maximum exterior illuminance.

For the retail store, it have been estimated the exterior illuminance provoked by the diffuse irradiance and the irradiance reflected by the surrounding buildings. The direct irradiance component has not been considered because it is not present at the shop window. The estimation has been done taken into account the retail store location (see Fig. 16), the irradiance data from a local weather station [34], the urban morphology in the store surroundings [35] and the luminous efficacy values [36] [37] (see example in Fig. 17). As a result, it has been obtained the illuminance histogram shown in Fig. 18 using the irrandiance data of an entire year. The resulting mean and maximum illuminance values for a year are 3645 lx and 6582 lx, respectively. In the other hand, it has been also estimated the maximum illuminance at the mannequins due to the lighting system of shop window, being its resulting value equal to 10,459 lx.

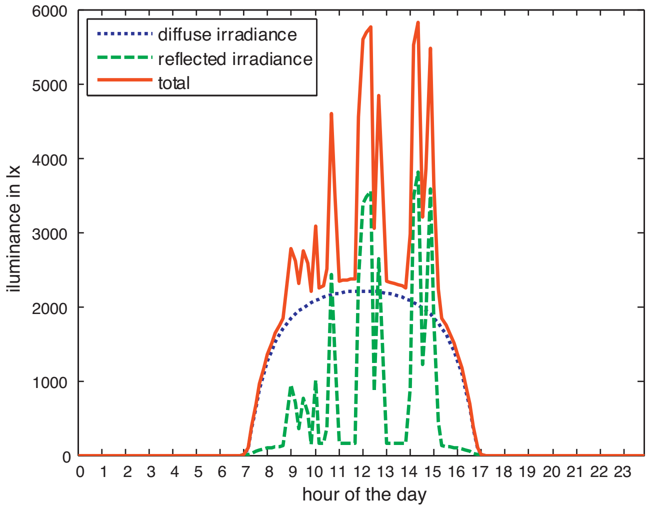

Fig. 17. Estimated illuminance components (provoked by the diffuse irrandiance, provoked by the reflected irradiance and total) for a partly overcast day.

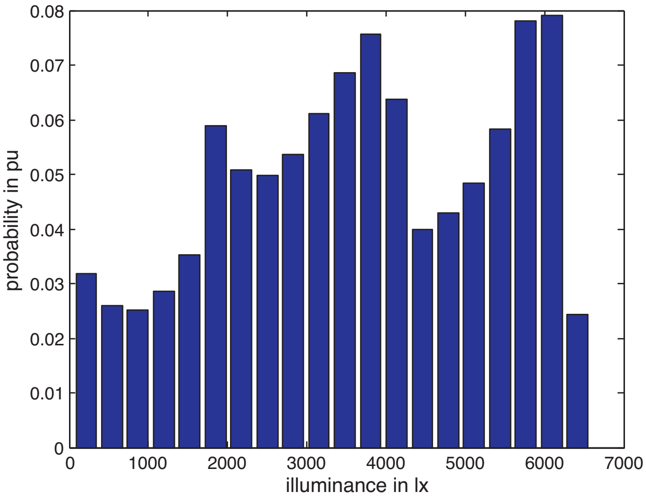

Fig. 18. Histogram of estimated exterior illuminance for a year.

During the protype tests (see Section III), the illuminance values at the exterior of shop window prototype have had a mean and a maximum value of 1340 lx and 3032 lx, respectively, during a day (see Fig. 11). The interior luminance due to the lamps was 3943 lx when the dimming level is set to one.

As a consequence, the resulting ratios K_{av} are 1:3 for the prototype and 1:2.7 for the retail store; and the K_{max} values are 1:1.3 for the prototype and 1:1.5 for the retail store. As a conclusion, the illuminance ratios are close enough in order to consider that the prototype has been tested in similar conditions than those in the real retail store.

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