Other Examples of Luminance and Luminance Gradient Maps

Case 1: exterior lighting at night

The front courtyard of Anderson Family Football Complex is shown above. The measurement was conducted on April 11 at 8:30 p.m. without daylight. The camera was mounted in front of the complex at a height of 1.42 m above the ground and aimed at the main entrance. The location of the camera was not recorded due to the lack of reference points in WCS (world coordinate system) coordinates. The X-Rite Macbeth color checker was vertically mounted on a paper box put on the ground in front of the camera for photometric calibration.

Figure 1 (a) - (d) show the spatial distribution of the luminance and luminance gradient values across the front courtyard of Anderson Family Football Complex. Figure 1 (e) (f) reveal the identified potential lighting hazards of the luminous environment, filtered with the lower threshold value 500 cd/m² and 500 cd/m²/pixel, respectively. It was found that the outdoor luminance distribution at night was at a low level except for the floodlights on the building facades and the logo lights mounted above the entrance canopy. As identified in Figure 1 (e), only the floodlight projected to the front walls and window glass and the visible wall washer mounted in front of the entrance might cause discomfort glare. The luminance gradient across the outdoor space was also at a mild level mostly less than 500 cd/m²/pixel, except for several highlight spots of light sources, as identified in Figure 1 (f). As shown in Figure 1 (d), the polarity of luminance gradient had dominant colors on the floodlights, the logo, the front pavement, and specular surfaces on top of the building facades. Conclusively, only the ground-mounted flood lights produced potential lighting problems, which were narrowly spaced and over illuminated.
**Figure 1** The luminance gradient maps obtained across the front courtyard of the Anderson Family Football Complex under electric light at night: (a) 2D luminance map, (b) 3D luminance gradient map, (c) 2D luminance gradient magnitude map, (d) 2D gradient direction map, (e) the 2D luminance map filtered with the lower threshold value $500 \text{ cd/m}^2$, (f) the 2D luminance gradient magnitude map filtered with the lower threshold value $500 \text{ cd/m}^2$/pixel.

**Case 2: courtyard under daylight**

The courtyard between Art & Design Building and Marvin Hall is shown above. The field measurement was conducted on July 17, hourly from 9 a.m. to 12 p.m.. During the measurement, the shadows of trees projected on the ground moved over time. The glass curtain wall of the bridge that connects the two buildings caused specular reflection of the sky, which was caught by the camera. The camera was mounted off the road close to the north wall of Art & Design Building, aiming at the X-Rite Macbeth color checker mounted on the opposite brick wall of the shelter with glass roof. The height of the camera was approximately 1.35 m above the ground. The location of the camera was not recorded due to the lack of reference points in WCS coordinates.

Figure 2 shows the 2D/3D luminance and luminance gradient maps obtained in the courtyard between Art & Design Building and Marvin Hall at 9:00 a.m. and 12:00 p.m.. In the early morning, the sun position was low, the courtyard was shaded by surrounding buildings and objects. As a result, as shown in Figure 2 (a1) (b1) (c1) (d1), the outdoor daylit environment was well diffused with mild luminance changes. One exception is the glass wall of the bridge, as shown in Figure 2 (e1) (f1) (g1), whose luminance values were high due to the reflected sky light. Later, when the sun moved to the highest position at noon, direct sunlight and strong shadows were introduced in the courtyard, resulting in high luminance changes on the ground, as shown in Figure 2 (a2) (b2) (c2) (e2) (f2) (g2). The polarity of the luminance gradient did not change as much as the magnitude by comparing Figure 2 (d2) to Figure 2 (d1). To identify potential lighting hazards, this study first adopted 2000 cd/m$^2$ and 2000 cd/m$^2$/pixel to plot Figure 2 (e1) (e2) (g1) (g2). However, 2000 cd/m$^2$ was the
lower threshold value for daylit interior spaces, not for the outdoor courtyard. As an adjustment to fit the increased adaptation level of outdoor environment, Figure 2 (f1) (f2) were plotted with another threshold value of 5000 cd/m², which was deliberately used in this study as an example. Since Figure 2 (g1) (g2) were almost blank, 5000 cd/m²/pixel was not necessary.
Case 3: daylit classroom with integrated electric lights

The classroom 1136 Learned Hall has a size of 11.13 m (width) × 6.95 m (length) × 2.87 m (height). The view to the sky through a strip window in the south wall is partially blocked by the opposite engineering library wall. The electric lights include nine ceiling recessed 2 × 4 troffers in the audience area (zone 1) and...
three more troffers to light the podium and the whiteboard (zone 2). The field measurement was conducted on
July 19, around 10:00 a.m. at four trials (i.e., integrated daylight and full electric lights, integrated daylight and
partial electric lights in zone 1, full electric lights, and partial electric lights in zone 1). Only the HDR images
taken at the first and the fourth trial are included in this paper. At the first trial, all window blinds were pulled
up to usher in maximum daylight, while all electric lights were turned on. At the fourth trial, all window blinds
were pulled down to block daylight, while only the nine ceiling recessed troffers in the audience area were
turned on. The camera was mounted close to the back entrance, 2.65 m away from the north wall and 1.04 m
away from the east wall, at a height of 1.30 m, aiming at the X-Rite Macbeth color checker put in the audience
area on a tabletop.

Figure 3 illustrates the luminance and luminance gradient maps across the classroom 1136 Learned Hall
under two different lighting conditions: integrated daylight and full electric light, and partial electric light in the
audience area only (no daylight, the louvers were pulled down). There was limited amount of daylight entered
through the south strip window at 10:00 a.m., whose view to the sky was blocked by the opposite engineering
library wall. As a result, the daylight had negligible impact on the light variance across the space, which was
revealed by comparing Figure 3 (a1) (b1) (c1) (d1) (e1) (f1) with Figure 3 (a2) (b2) (c2) (d2) (e2) (f2). Thus,
this classroom interior was not considered as a daylit space. The lower threshold values of 500 cd/m² and 500
cd/m²/pixel were used to identify the potential lighting hazards, as shown in Figure 3 (e1) (e2) (f1) (f2). Only
the ceiling recessed 2 × 4 troffers might cause discomfort glare. In addition, as shown in Figure 3 (c1) (c2),
when the two ceiling recessed troffers in the podium area were turned off, the luminance distribution on the
whiteboard was more uniform also at lower level. Figure 3 (d1) (d2) revealed the well-diffused light distribution
on the floor and ceiling. Dominant colors of the luminance gradient polarity were only found on the edges of the
troffers, the window louvers, and the metal surfaces of chairs and the whiteboard.
Figure 3 Luminance and luminance gradient map of Classroom 1136 Learned Hall, (a1, a2) 2D luminance map, (b1, b2) 3D luminance gradient map, (c1, c2) 2D luminance gradient magnitude map, (d1, d2) 2D gradient direction map, (e1, e2) the 2D luminance map filtered with the lower threshold value 500 cd/m², (f1, f2) the 2D luminance gradient magnitude map filtered with the lower threshold value 500 cd/m²/pixel.