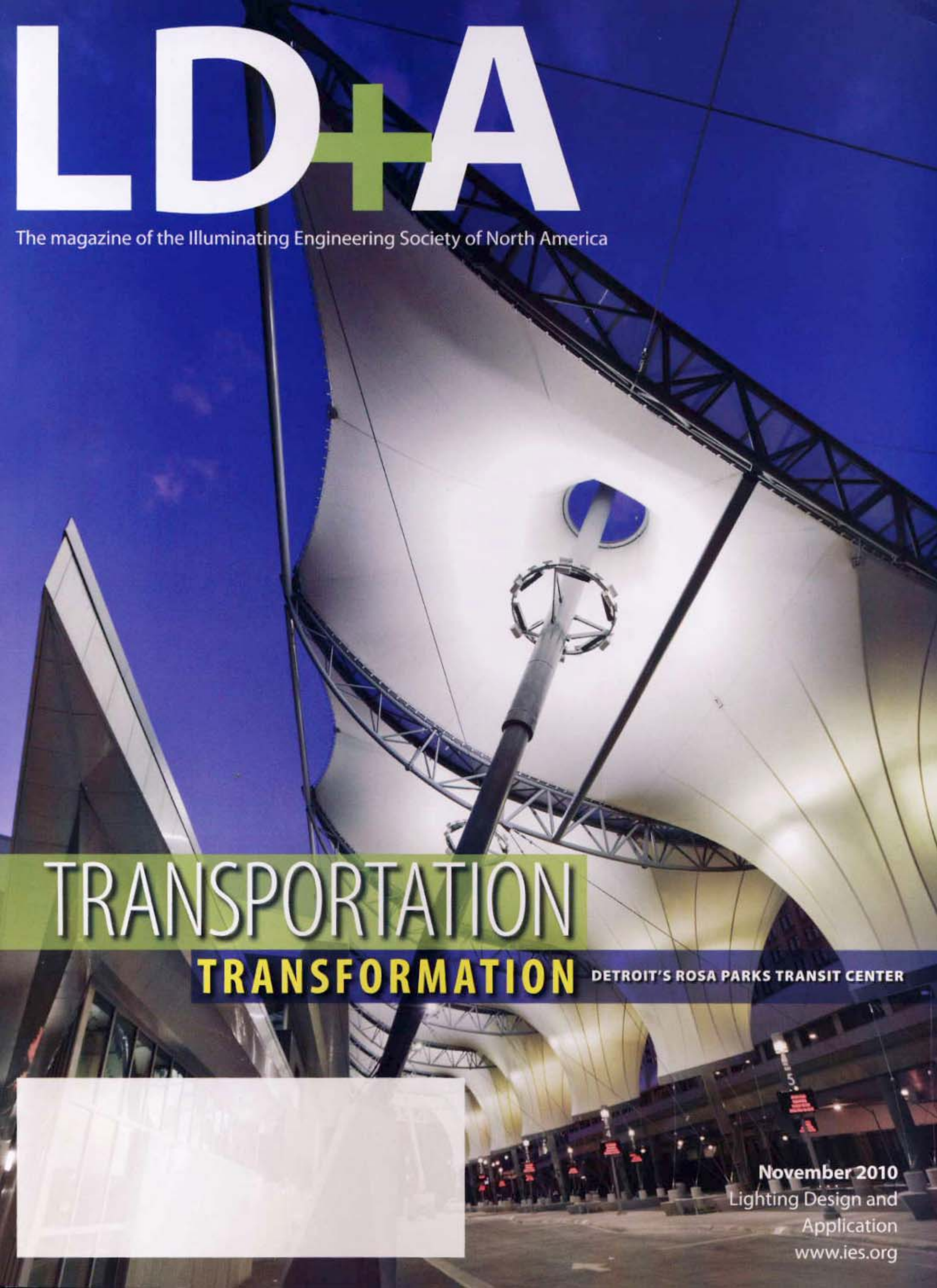
# LD+A

The magazine of the Illuminating Engineering Society of North America



## TRANSPORTATION TRANSFORMATION

DETROIT'S ROSA PARKS TRANSIT CENTER

November 2010

Lighting Design and Application

www.ies.org

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High dynamic range (HDR) imaging, originally developed and used for research purposes, now is becoming a consumer term as several consumer cameras and even mobile phones, such as the latest version of the iPhone, include some form of HDR capabilities, mainly for improved photography.

It long has been known that the eye sees luminance distributions rather than illuminance on surfaces. Illuminance is a metric of the density of luminous flux arriving at a surface from all possible directions. This provides information about the amount of light reaching a work surface, but no information about directional input of light at the eye, which is what really matters to determine visual comfort.

The reason to use illuminance is the inexpensive, quick and easy way to measure it, versus the relatively expensive and cumbersome way of measuring luminance distributions.

HDR imaging has been used for research purposes for many years and is now common practice, as new digital cameras and specialized software have been developed to speed and facilitate processes. HDR imaging involves a series of photographs of a luminous scene from the same viewpoint, ranging from fully underexposed to fully overexposed images, which then are processed by software to produce luminance maps [Reinhard 2006].

As digital cameras and software become mainstream, so does the consideration of HDR imaging in lighting practice, pointing away from using workplane illuminance as a sole determining metric for design and toward recognizing the importance of luminance distribution in achieving comfortably and functionally lighted spaces.

Luminance maps from viewpoints of interest are the most effective way to address glare issues. This is particularly the case for daylighting, given that glare is a primary concern in daylighted spaces, and luminance distribution from the occupant's viewpoint is important to assess glare. For example, in an office daylighted by a window, workplane illuminance is the same for both window-facing occupants and occupants facing away from the window. As **Figure 1** suggests, visual comfort and glare in these two viewing positions are likely to be very different. In situations like these, workplace illuminance won't discern between the two viewing positions, but luminance distribution arriving at the occupant's eye will.

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Until a few years ago, measuring luminance distributions was prohibitively expensive for most applications, requiring sophisticated equipment and effort. Since then, HDR digital photography has emerged as an inexpensive and easy-to-use technique for producing luminance maps that are accurate enough for many lighting applications. **Figure 2** shows a luminance map of a room illuminated by two tubular daylighting devices. Luminance mapping allows, for example, the quantitative characterization of glare from these devices, something that would be impossible to do using illuminance measurements.

Several systems exist today to produce luminance maps using HDR photography. Photolux [Dumortier 2005] is a commercially available system that uses the Nikon Coolpix 5400 camera and a fisheye lens (calibration coefficients can be obtained for other lenses for a fee). The software runs on the Windows operating system. Photosphere [Ward 2002] runs on MacOS and is a free system with which any camera and lens can be used, although it requires some equipment calibration procedures. It supports many standard HDR image formats, as well as performing some image enhancement. HDR images also can be generated online using WebHDR.[1]

Given the dynamic nature of daylight in daylighting applications, however, it becomes important to acquire luminance data over time. This can be done with a high-end, single-lens-reflex digital camera and a computer program that controls the camera and stores the data [Lee 2007]. For time-lapse luminance mapping to be widely accessible and gain wider use, simpler and less expensive equipment will be required. In the course of the authors' research at the California Lighting Technology Center, a particularly simple, versatile and inexpensive solution has been identified that requires a point-and-shoot digital camera, free software and, in most cases, a tripod.

## SIMPLE SYSTEM

The system presented here includes:

- Canon point-and-shoot digital camera (Ixus or PowerShot series)
- Memory card and card reader
- Tripod (for most uses)
- Canon Hack Development Kit software and script for automated time-lapse photography
- Photosphere software

Canon Hack Development Kit (CHDK)[2] is free software that allows many models of Canon point-and-shoot digital cameras to perform

**Figure 1: Fisheye images of side-lighted office for occupant facing away from window (left) and occupant facing the window (right).**

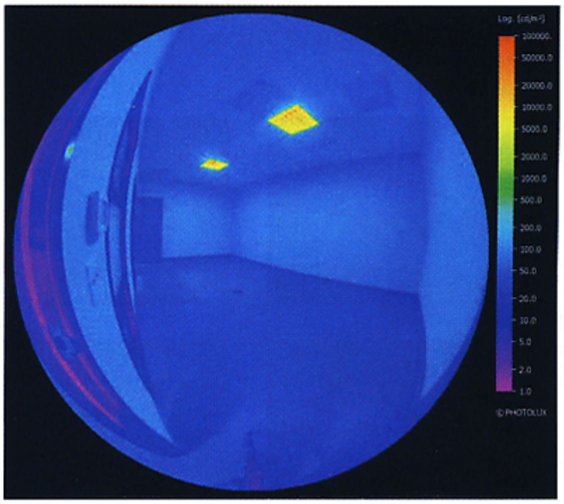

**Figure 2: Luminance map obtained by high-dynamic-range photography.**

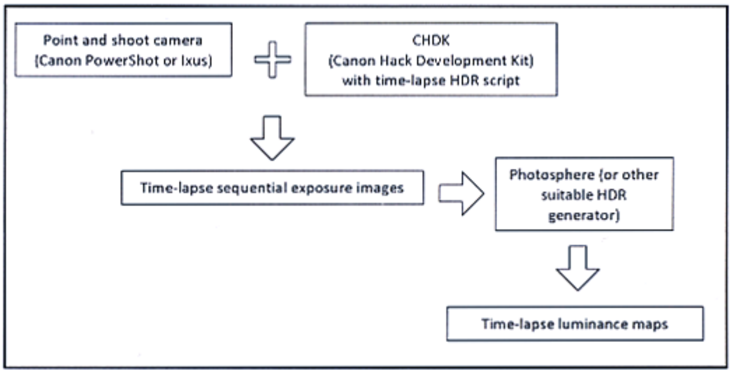


**Figure 3: Time-lapse luminance mapping workflow.**

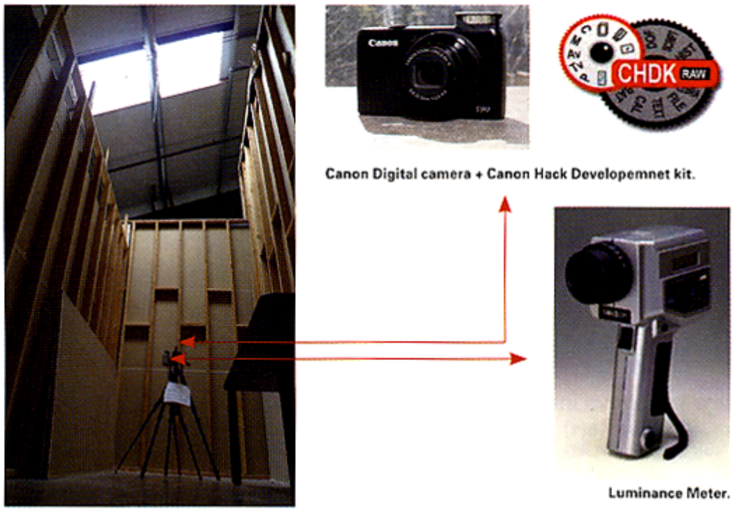


**Figure 4: Time-lapse luminance mapping system.**

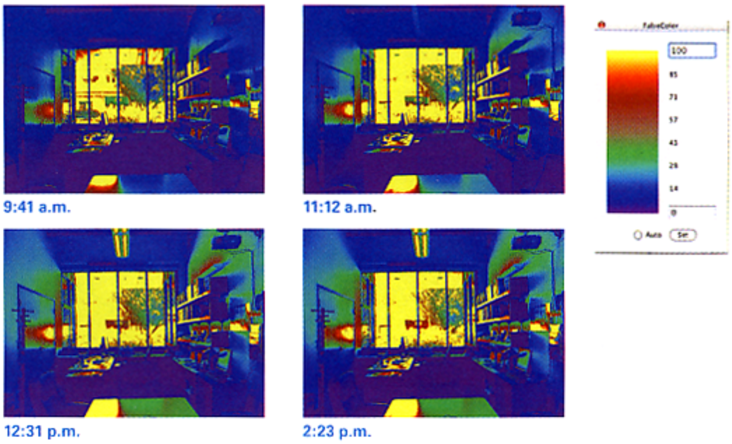


**Figure 5: Time-lapse luminance maps. Luminance values in cd/m$^2$.**

functions not normally allowed by the camera's built-in software. CHDK is installed on the camera's memory card and allows scripts to be written using two simple languages (ubasic and Lua), a feature that can provide the user with versatile control of the camera's functions.

In the system presented here, it is used in conjunction with Photosphere to inexpensively obtain luminance maps of a particular scene over a period of time. The diagram in **Figure 3** depicts the process. The camera is mounted on a tripod, pointed at the scene of interest, and fitted with the memory card that contains the CHDK software and time-lapse HDR script installed. The script is activated through the camera's user interface and the system then is left to acquire images for the desired period of time, which can be limited by either memory card capacity or battery life.

HDR imaging requires the sequential acquisition of images of varying exposures. Time-lapse HDR imaging involves performing that procedure at regular intervals. A simple script was developed for that purpose and can be viewed at *http://cltc.ucdavis.edu/images/_downloads/ubasicscript.pdf*. It was tested using CHDK and a Canon PowerShot S90.

The image acquisition portion of the system is depicted in **Figure 4** at the California Lighting Technology Center's Daylighting Lab. The configuration shown includes a luminance meter used to confirm the accuracy of the results–this would not normally be required in a field application.

## FIELD TEST

A test of this system was conducted by monitoring the luminance of an office window and its adjacent areas from 9:41 a.m. to 2:23 p.m. September 16, 2010. The images taken by the camera at the end of this period were processed using Photosphere into a series of time-lapse luminance maps, four of which are shown in **Figure 5**.

The capability for generating luminance maps using HDR software, such as Photolux, Photosphere or WebHDR, has been available for a few years already, and the necessary equipment, software and information are becoming more readily available. As the use of luminance maps through HDR imaging increases, lighting design is entering a new era of significant improvement through designing and evaluating luminous environments based on what the eye sees rather than how much light arrives at surfaces.

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1. Jacobs, Axel. "What is HDR?" *WebHDR*. Axel Jacobs, 11 May 2008. Web. 16 Sep 2010. <http://luminance.londonmet.ac.uk/webhdr/>.

2 "CHDK." *Wikia*. Wikia. Web. 16 Sep 2010. <http://chdk.wikia.com/wiki/CHDK>.

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