GOTHIC: Glare Optimizer Tool for High-Dynamic-Range Images and Content with Implementation in Video

Mina Choi, Fahad Zafar, Joel Wang
CDRH, FDA

Gianni Ramponi
Univ. of Trieste

Wei-Chung Cheng
CDRH, FDA

Luigi Albani
Barco, FIMI

Aldo Badano*
CDRH, FDA

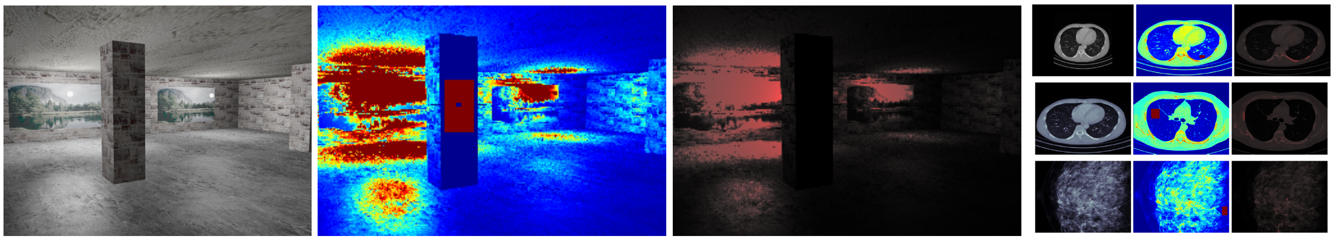

Figure 1: GOTHIC *in action for CG image and medical images: An HDR image is analyzed to determine each pixel contribution to the augmented contrast detection thresholds due to veiling glare experienced by a human subject at a chosen location in the image (see middle image with region-of-interest and marked target location). The pixel map of the veiling glare effect is shown as a red-channel overlay on the right-most images. This analysis is then iterated for different visualizations until a tolerance level for the degradation due to veiling glare is attained. The images show the application of* GOTHIC *to computer-generated and medical images. Credit: Image from CG-HDR Modified HDRLighting C++ Sample. Microsoft DirectX SDK February 2012 Release, Lung Image Database Consortium and TG18.*

Introduction: The luminance range of the sun to the night sky is approximately 14 orders of magnitude. Current display technology can present approximately three orders of magnitude, however this number is increasing as High-Dynamic-Range (HDR) technology develops to further emulate reality [Seetzen et al. 2004]. Another benefit to HDR technology is the increased bit-depth enabling the display of more information. However, a major limitation in the perception of added bit-depth is veiling glare. The increased luminance range in HDR displays have the ability to produce glare sources that can reduce the visible contrast in neighboring dark areas. This effect is especially undesirable in the visualization of scientific data and in medical images. The HDR presentation must be optimized so that the benefits of a wide luminance range are not diminished by glare in the human visual system. One important question is, what is the largest luminance range that avoids these veiling glare effects while presenting the most bit-depth? We have found that the answer is highly dependent on the spatial and luminance distribution in the image. Many models have been proposed to estimate the veiling glare in a given image. A well known model is High-Dynamic-Range Visual Difference Predictor 2 (HDR-VDP-2) [Mantiuk et al. 2011], a calibrated method able to determine the visibility of differences in HDR images. Building on a number of previous metrics of visible difference, this model operates in a broad range of viewing conditions, from scotopic to photopic vision. More importantly, HDR-VDP-2 can be used to represent the effects of visual glare in signal detection. The inputs of the HDR-VDP-2 are a luminance map of an image, a reference image, and an image with the target. The software outputs the probability of target detection accounting for various visual effects including veiling glare.

Approach: We describe a novel tool using our own glare model for optimizing the detection of subtle features in dark regions of high-dynamic-range (HDR) images by minimizing the deleterious effect of veiling glare in the human eye. Our method relies on predictions of contrast detection thresholds based on psychophysics measurements and modeling of the HDR display device characteristics [Choi et al. 2012]. We first calculate the appropriate luminance mapping on a HDR display that minimizes veiling glare effects within the display to isolate perceived glare. We measured contrast detection thresholds for a Gaussian target on a noisy background with the presence of a veiling glare source. The veiling glare source was a concentric ring with varying radii and illuminances. The experimental results were used to construct the model which finds the contrast detection threshold dependent on angular distance and illuminance of glare source similarly to the CIE disability glare function. We use the empirical glare model to develop a more versatile, image-dependent model for the assessment of complex HDR images. The model predicts human contrast detection threshold for any specified location in the image. The image-dependent model is validated with observer studies for synthetic, medical, and natural images. Once HDR images (and specific locations within those images) with significant veiling glare effects are identified, GOTHIC selects a luminance map that reduces the glare in the image presentation while attempting to maintain the widest possible luminance range and depending on a tolerance factor for contrast reduction. GOTHIC does not account for color effects or transient glare effects.

Results: The figure above shows GOTHIC in action for one computer generated image, two chest computed tomography images, and one mammogram. The intensity of the red overlay in the third image for each set represents relative contributions of the pixel to the glare effect. GOTHIC can be of practical use in applications such as gaming, video, and dynamic medical image viewers. We demonstrated the optimization in a computer generated HDR video sequence. It is currently being improved to be implemented with sub-ms execution times (a 1000x increase with respect to its current MATLAB implementation). Also, we are investigating a GPU-based implementation in conjunction with approaches to minimize the actual computation load.

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*e-mail: aldo.badano@fda.hhs.gov

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