Survey and Evaluation of Tone Mapping Operators for HDR Video

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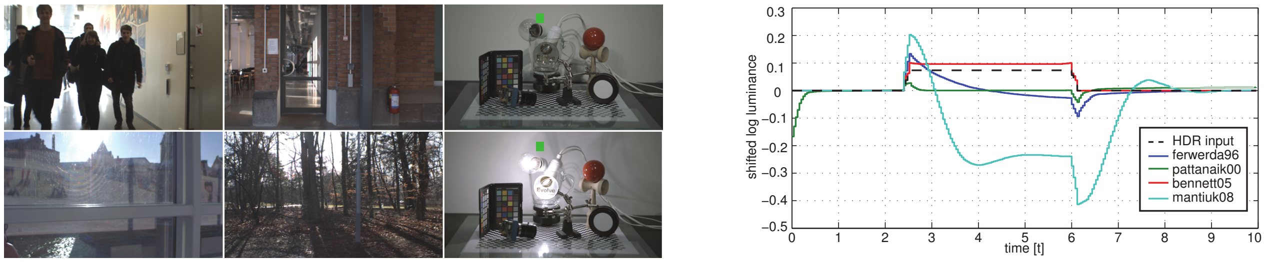

Figure 1: ***Left:*** *The HDR-video sequences used in our evaluation exhibit strong local contrast changes, rapid variations in local and global intensity as well as spatio-temporal variations.* ***Right:*** *the plot illustrates how different a set of representative TMOs from our evaluation, see legend, responds to the same HDR input. The plot shows the log luminance of the temporal variation of a pixel under the green square as the light bulbs are turned on and off. Note that the plots are, for presentation purposes, shifted along the y-axis to start at the same value.*

1 Introduction

This work presents a survey and a user evaluation of *tone mapping operators* (TMOs) for *high dynamic range* (HDR) video, i.e. TMOs that explicitly include a temporal model for processing of variations in the input HDR images in the time domain. The main motivations behind this work is that: robust tone mapping is one of the key aspects of HDR imaging [Reinhard et al. 2006]; recent developments in sensor and computing technologies have now made it possible to capture HDR-video, e.g. [Unger and Gustavson 2007; Tocci et al. 2011]; and, as shown by our survey, tone mapping for HDR video poses a set of completely new challenges compared to tone mapping for still HDR images. Furthermore, video tone mapping, though less studied, is highly important for a multitude of applications including gaming, cameras in mobile devices, adaptive display devices and movie post-processing.

Our survey is meant to summarize the state-of-the-art in video tone-mapping and, as exemplified in Figure 1 (right), analyze differences in their response to temporal variations. In contrast to other studies, we evaluate TMOs performance according to their actual intent, such as producing the image that best resembles the real world scene, that subjectively looks best to the viewer, or fulfills a certain artistic requirement. The unique strength of this work is that we use real high quality HDR video sequences, see Figure 1 (left), as opposed to synthetic images or footage generated from still HDR images.

2 Evaluation of TMOs for video

From our survey of TMOs, we have selected eight representative TMOs that perform temporal processing, and thus are aimed at HDR-video input. For the evaluation, we divide the TMOs into two classes based on their intent: **Visual System Simulators (VSS)**, that include the temporal domain by simulating the limitations and properties of the human visual system, and **Best Subjective Quality (BSQ)** operators, that are designed to produce the most preferred, or best looking, images or video in terms of subjective preference or artistic goals. The evaluation, including 36 participants, was carried out using pairwise comparisons between a set of HDR-video sequences processed using the selected TMOs. The input video sequences exhibited up to 24 f-stops of dynamic range. For the VSS TMOs, the participants were, in each trial, asked to judge which of the two video clips that looked most like what they would expect the real scene to look like. For the BSQ operators the participants were asked to select the video clip that subjectively looked best. For a fair comparison, the parameters for each TMO used in the evaluation were determined by an expert user in a pre-study.

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3 Results

The results of the study, shown in Figure 2, revealed that many complex and in particular local video operators introduce artifacts: flickering, ghosting, over-saturated colors. Therefore, unexpectedly, less sophisticated global operators (ferwerda'96 and pattanik'00) received higher scores in the comparison of the VSS operators. This shows importance of testing video operators with challenging sequences, which contain both high spatial and temporal contrast changes. The results for BSQ operators revealed another important issue, most often disregarded by operators: the subjective quality is much penalized if tone-mapping reveals noise and other artifacts of camera HDR capture. Therefore, the operators need to take into account the quality of input HDR sequence. Overall, the study showed that the problem of video tone mapping is not by far fully solved and identified the areas that need further improvement.

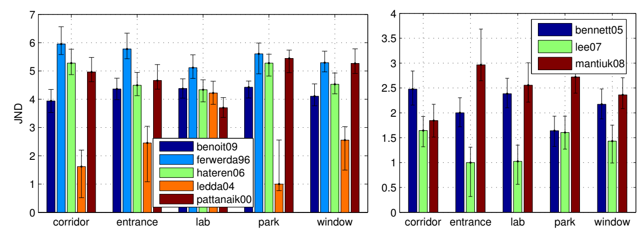

Figure 2: *Results of the evaluations for VSS (left) and BSQ (right) TMOs. The results are scaled in JND units (the higher, the better) under Thurstone Case V assumptions, where 1 JND corresponds to 75% discrimination threshold. Note that absolute JND values are arbitrary and only relative differences are meaningful. The error bars denote 95% confidence intervals computed by bootstrapping.*

Acknowledgments

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References

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