Æ-HDR: an Automatic Exposure Framework for High Dynamic Range Content

Paolo Banterle
(banterle@unisi.it)
University of Siena

Francesco Banterle
(f.banterle@warwick.ac.uk)
University of Warwick

WDL Digital Innovation

Introduction

Automatic exposure (AE) is a common method implemented in consumer cameras to calculate the best exposure that tries to minimize under and over exposed pixels for a scene [Neumman et al. 98]. In this work we present some applications of a generalized framework for an AE algorithm for high dynamic range (HDR) imaging. Our AE framework can be used for interactive visualization of HDR images on low dynamic range (LDR) and HDR monitors.

The Algorithm

Our framework, see Figure 1, can be divided in three steps:

1. Exposure map calculation
2. Exposure calculation
3. Motion Stabilization

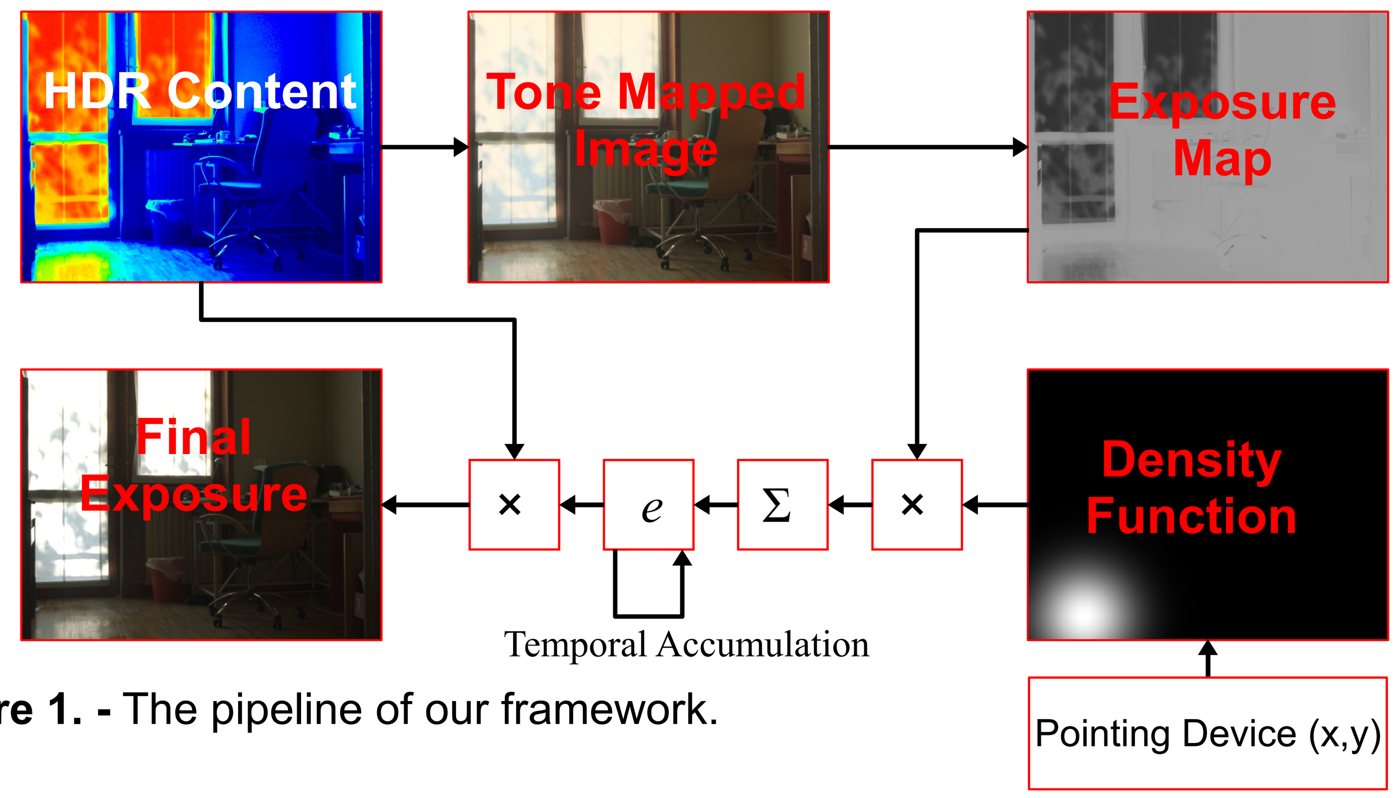

Figure 1. - The pipeline of our framework.

EXPOSURE MAP CALCULATION:
The exposure map, E_{map}, defines for each pixel the exposure value that a tone mapping operator (TMO) assigned to it. This can be calculated very easily as the ratio between the tone mapped luminance L_d and the original HDR luminance L_w.
In our implementation we used the Tone Photographic Operator [Reinhard et al. 2005], see Figure 2 for an example.

EXPOSURE CALCULATION:
We decided to calculate the final exposure as a weighted average of a region of interest (ROI), with an arbitrary shape.

Figure 2. - An example of the calculation of the exposure map: on the left a false color HDR image, in the center the same image tone mapped using the tone photographic operator, on the right the exposure map calculated as the ratio between the tone mapped image and the HDR one.

To a ROI is associated a density function $p(i,j)$ which defines weights for the average. So the final exposure is calculated as:

$$e = \sum_{i,j} p(i,j) E_{map}(i,j)$$

In our implementation we used a circle as ROI and a Gaussian function as density function (see Figure.2 for an example):

$$p(i,j) \; = \; \frac{1}{\sigma\sqrt{2\pi}} \exp(-(i - c_x)^2 \; + \; (j - c_y)^2/2\sigma^2)$$

MOTION STABILIZATION
When the ROI is moved fast between a very dark region and a very bright one, flickering can occur. To avoid this problem we introduced motion stabilization as the last step of our framework. We modeled it using a simple average of n exposures calculated in the last 1/4s, a value that we found to give good results from our experiments. The new exposure is calculated as follows:

$$e' \; = \; \sum_{i=0}^{n} e_i \exp(-(\tfrac{i}{n})^2/(2\sigma_t^2))$$

At this point the original HDR image is scaled by this exposure, e'. Finally, gamma correction is applied to the image, see Figure 4.

Figure 3. - An example of density map and final exposure: on the left a tone mapped image, in the middle right the density function which is pointing at the reflection below the French window, on the right the final image using AE.

Applications

The main application of our framework is an easy tool for exploring HDR images or videos. Moving the ROI with a pointing device enables users to visualize regions of interest without the problem of changing the exposure for an areas that is needed to explore. Furthermore, the application of an eye-tracker would improve the experience allowing automatic pointing and simulating real world experience. The advantages are mainly two: **reduction of color shifting** caused by TMOs and **speed** because only a linear slice of information is needed for each ROI .We implemented our framework on the GPU using shader model 3.0, and it performed more than **200fps** for images and videos at 1080p on an Intel Pentium 4 HT 2.8GHz, 1Gb of Ram, and GeForce 7800 with 256 Mb of ram.
A second possible application is the visualization of HDR images or video on an HDR display. As shown in [Akyüz et al. 2007] a LDR image or video can provide an HDR experience using inverse tone mapping [Banterle et al. 2006]. Therefore, an AE for HDR images/videos can be a proper solution. Furthermore, our framework can be seen as a compression tool, indeed HDR content can be processed using our framework and stored using common LDR standards. In particular for HDR videos the ROI can be positioned in a way that follows a particular object or a path, for keeping its details using tracking algorithms or matting masks, see Figure 4.

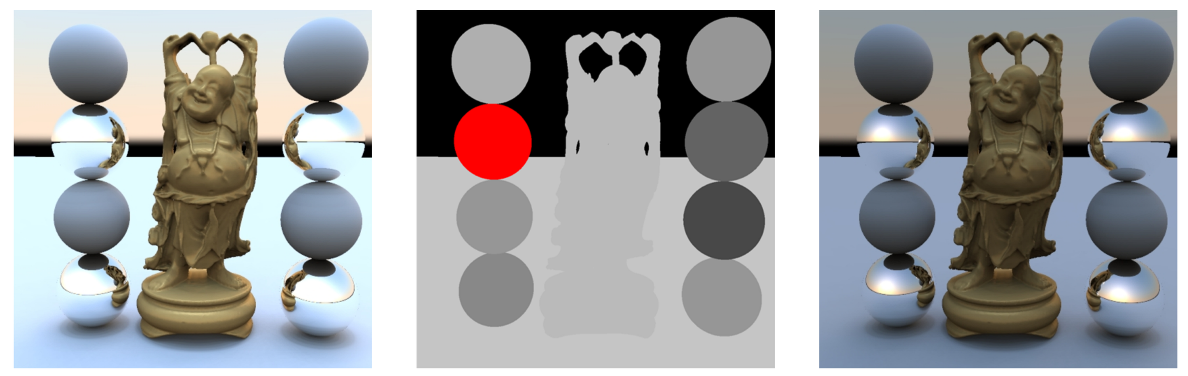

Figure 4. - An example of AE using additional information: on the left a rendered image at f-stop 0, in the middle the additional information (mask) where ROI is the circle in red, on the right the rendered image with the exposure for the red ball calculated with our framework. The Happy Buddha model is courtesy of the Stanford Graphics Group.

References

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