Histogram-Based HDR Video

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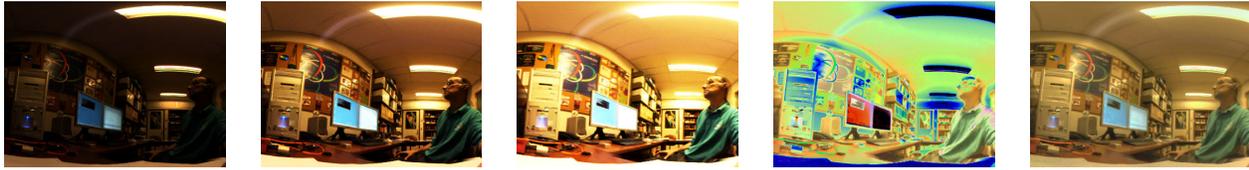
Figure 1: *Captured LDR images with exposures -1.5 EV, 0 EV, +1.5 EV; HDR image in pseudocolor; and tonemapped image*

High Dynamic Range Imaging has gained tremendous importance in recent years. Technology advances consolidated this technique regarding software, hardware and applications. In terms of software, besides programs developed by pioneer researchers, such as HDRShop and Photosphere, HDR support has been incorporated in commercial imaging products, such as Photoshop CS. Moreover, a wide range of HDR formats have been established, for example ILM's OpenEXR and JPEGHDR. In terms of hardware, camera manufacturers are becoming increasingly aware of the value of tone resolution over spatial resolution, thus facilitating user access to raw image data. At the same time, specialized HDR cameras, such as SpheronVR, have appeared in response to market demands – not to mention the still incipient development of HDR displays, In terms of applications, the special effects industry have embraced Image-Based Lighting techniques, which completely rely on HDR data. Also, amateurs and professional photographers alike are showing great enthusiasm for the creative possibilities of HDR. As an evidence of this fact, the Flickr group on HDR has currently 10,000 members exhibiting more than 55,000 tonemapped pictures.

Among the various HDR related topics, the reconstruction of high dynamic range data from differently exposed images is arguably the most basic problem. It not only makes possible to capture HDR imagery with regular cameras, but is also at the core of photometric calibration algorithms. In the traditional setting, HDR reconstruction applies only to still images, where both the camera and the scene are assumed to be static. The problem under this formulation has been extensively studied and is virtually solved. A more challenging task is the HDR reconstruction from video because it requires a programmable camera and the data is dynamic. Perhaps for this reason, there exists a few solutions to this problem so far. On the hardware side, improved sensors are being incorporated into specialized HDR video cameras, such as the IMS-CHIPS. On the software side, the main reference is the work by [Kang et al. 2003].

Most algorithms for HDR reconstruction from still images rely on pixel correspondences to relate differently exposed values of the same point of the scene in order to recover the camera response function and properly map radiance values. The main difficulty with dynamic image sequences is that in this setting, it is no longer possible to use pixelwise correspondence directly. Therefore, some sort of motion estimation is needed. What makes this problem particularly hard is that the exposure varies from frame to frame while the scene changes. Classical vision methods for motion estimation, such as optical flow, assume that the exposure is constant. In order to make such an approach work the only option is to consider the interleaved pattern of exposures in the HDR video sequence – this is actually the strategy adopted in [Kang et al. 2003]. The main disadvantage of this type of solution is that temporal resolution suffers considerably with consequent loss of precision.

We introduce a novel approach for video HDR based on histograms. Our solution is efficient, simple to implement, robust to noise and insensitive to motion. The algorithm has three steps: first, it uses histograms to estimate the camera response function and the radiance mapping; second, it applies histogram correspondences to register neighbor frames; third, it computes pixel radiances performing ghost elimination. Note that histogram information is an integral part of this method in every step. It allows taking into account values from all pixels, but on the average sense. Thus, making the algorithm robust to noise. Most importantly, it gives a principled way to establish correspondences between differently exposed images, what makes the algorithm able to track motion in the scene.

The key idea behind our method is that exposure changes preserve monotonicity of pixel values. Intuitively, the n brightest pixels in a frame with exposure e_1 correspond to the n brightest pixels in a subsequent frame with exposure e_2, even though their actual values are not the same. In that way, using the cumulative histogram it is possible to obtain a correspondence between exposure values in two images. We remark that this principle only fails in the case of changes in visibility or illumination – but this does not affects the algorithm because it typically occurs in a small percentage of the pixels and it is averaged out by the histogram.

The overall structure of the algorithm is as follows:

Step 1- Photometric Calibration and Radiance Mapping Estimation:
- Compute cumulative histograms for each image;
- Merge cumulative histograms to find corresponding pixel values;
- Compute Radiance Mapping using histogram correspondences.

In this step, any HDR reconstruction method can be used. Here we employed a modified version of [Robertson et al. 1999].

Step 2 – Histogram-based Registration:
- Find the best histogram cut for each pair of images;
- Threshold images based om histogram cuts;
- Perform multiresolution alignment of the binary images.

Step 3 – Radiance Map Reconstruction with Ghost Elimination:
- Transform neighbor images to current image coordinate system;
- For each pixel compute variances of radiance values over images;
- Blend radiance values using weights based on variances.

Figure 1 shows the result of applying our HDR algorithm to one frame of a video sequence. The images were acquired with a Ladybug2 camera from Point Grey Research.

References

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