Extrapolative Lightspace Method for HDR Video Exposure Selection

Sarang Nerkar, Ryan Janzen, Pete Scourboutakos, and Steve Mann

Abstract—**We propose a method to automatically adjust multiple exposure-value settings for HDR video compositing.**

The method uses imagespace-to-lightspace post-conversion and tonal extrapolation to iteratively select optimal exposure settings, as opposed to present systems, which use manually set settings. The limiting factor becomes the image sensor as opposed to the implementation of the algorithm, as in present systems. By choosing the exposure settings with the described algorithm, the high dynamic range sampling process can be adapted to various lighting environments. This algorithm is especially useful for ultra low power capture of optimally selected exposures which can be processed later using well-known HDR compositing methods.

I. Introduction

In high dynamic range (HDR) compositing, multiple image exposures of a scene are taken while adjusting the exposure setting to different values, thereby covering a wider dynamic range then that of a single image exposure. In this way, it is possible to overcome the limited dynamic range of a camera.

One aspect of this research is to intelligently combine the data from multiple exposures, while accounting for the nonlinear response of cameras [3] [4] [5] [6] [7] [8] [9]. One method is to reverse the nonlinearity for each exposure, and then weight each pixel in each exposure according to the response function's derivative at that pixel brightness, thus giving a measure of degree of certainty each exposure's pixel gives to the combined measurement [3][5].

A critical step is the choice of exposure settings.

HDR exposure optimization was developed for time-varying signals [1]. This work found a set of constraints used to control exposure settings, based on the properties of a time-varying signal such as light or sound. This method used an "exposure packing" dynamic range to compute the values of exposure gains. Specifically for imaging, we could apply this to cameras by adding a compensation factor for the camera's nonlinear response.

II. Method

To overcome these previous limitations, we convert the tonal range of the image into an equivalent tonal range of physical light levels, for each pixel. The available tonal range given from an image is referred to as imagespace [10], and typically ranges in value from 0 to 255 for an 8-bit image, across red, green and blue channels.

Instead we calibrate a nonlinear model of the camera's response function, which converts a pixel value into an estimated true quantity of light. This true, physical range of values is referred to as lightspace [10].

The M exposure settings, $\{E_1, E_2, E_3, ..., E_M\}$, were chosen as follows:

1) Lowest (darkest) exposure value E_1 is set at 1/3 of the difference between the minimum possible exposure setting E_{min} and maximum possible exposure setting E_{max}.
2) Highest (brightest) exposure value E_M is set at 2/3 of the difference between the minimum possible exposure setting E_{min} and maximum possible exposure setting E_{max}.
3) Camera set to E_1, and image I_1 captured.
4) Camera set to E_M, and image I_M captured.
5) Image I_1 is converted to lightspace image L_1.
6) Image I_M is converted to lightspace image L_M.
7) Histogram H_1 formed from L_1.
8) Histogram H_M formed from L_M.
9) Number of saturated pixels s_1 calculated from I_1.
10) Number of saturated pixels s_M calculated from I_M.
11) Affine function derived from s_1 and s_M, and its intercept is calculated at a predicted value of zero pixels saturated. This leads to a new value of E_M.
12) Number of zero-saturated pixels u_1 calculated from H_1.
13) Number of zero-saturated pixels u_M calculated from H_M.
14) Affine function derived from u_1 and u_M, and its intercept is calculated at a predicted value of zero pixels saturated. This leads to a new value of E_1.
15) Repeat to (3).

III. Results

We used an ONSemi NT9P031 image sensor interfaced to EVB1005 development board, which outputted 12-bit images whose pixel-values ranged from 0 to 4095 in each of the red, green, and blue channels.

An example of the system's operation is illustrated in Fig. 1. Fig. 1 shows the time evolution of two exposures (one dark and one light), until the algorithm is satisfied that sufficient information is known about every pixel, i.e. no pixel is saturated in both input exposures. The final result is a composited image, where each pixel is composed of tonal information from at least one of the two corresponding input exposure pixels. In all cases, the two corresponding input exposure pixels are

978-1-5090-4571-6/16 $31.00 © 2016 IEEE
DOI 10.1109/ISM.2016.80

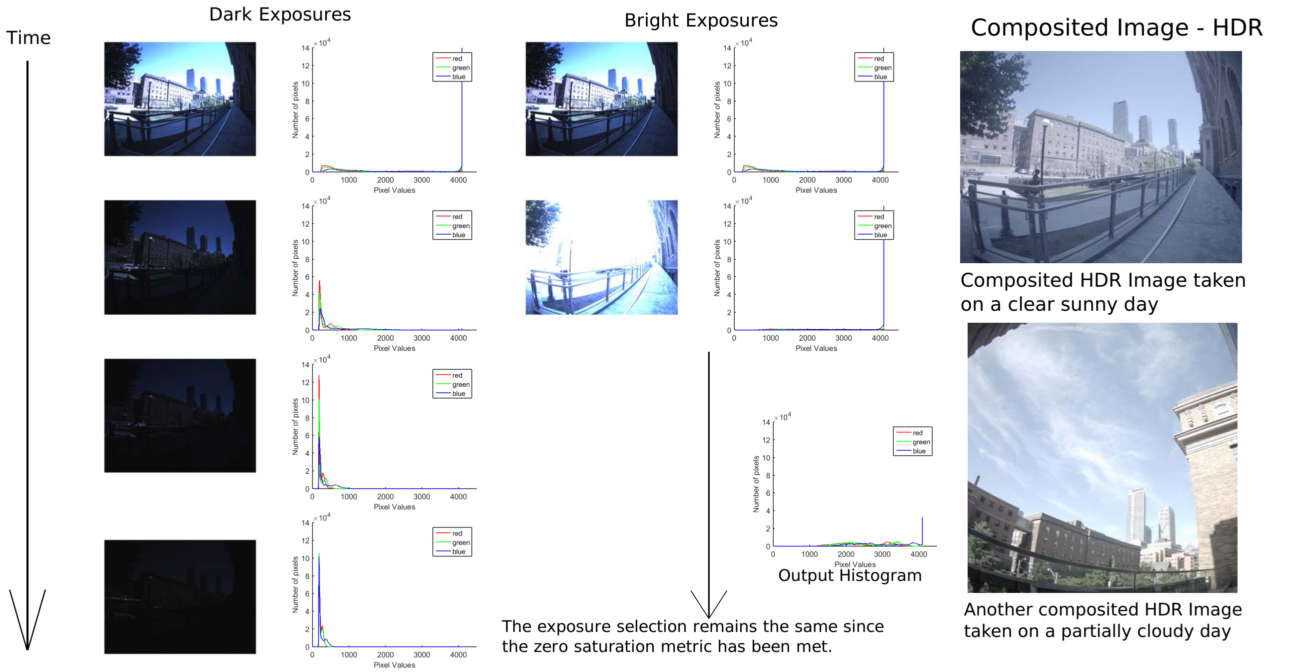

Figure 1. System operation illustrated, showing the dynamic adjustment of two exposure settings, combined into an HDR image. The exposures are combined in a process from left to right in the diagram. Time evolves from top to bottom in this diagram.

combined by first converting the 12-bit imagespace pixel values to lightspace by reversing the camera's response function, merging, and re-doing the response function to convert back to imagespace. Fig. 1 also shows another image composited using the presented algorithm under different environmental conditions.

IV. Conclusion

The new method proposed has been used to automatically select exposure values in order to optimize the exposures of multiple images captured for the purpose of HDR compositing. By choosing the exposure values with the algorithm presented, a high dynamic range is maintained irregardless of the environment, for example on both a sunny and a cloudy day.

Thus, we have devised a new method for automatic exposuresetting control, to enable HDR compositing in any situation.

V. References

[1] R. Janzen and S. Mann, "High dynamic range simultaneous signal compositing, applied to audio," in Proc. IEEE CCECE 2012, Montreal, April 29 to May 2 2012.

[2] P. Lapray, B. Heyrman, and D. Ginhac, "Hdr-artist: An adaptive real-time smart camera for high dynamic range imaging," Journal of Real-Time Image Processing, 2014, http://link.springer.com/article/10.1007/s11554-013-0393-7.

[3] S. Mann and R. Picard, "Being 'undigital' with digital cameras: Extending dynamic range by combining differently exposed pictures,"

[4] S. Mann, "Comparametric equations with practical applications in quantigraphic image processing," IEEE Trans. Image Proc., vol. 9, no. 8, pp. 1389–1406, August 2000, iSSN 1057-7149.

[5] "Compositing multiple pictures of the same scene," in Proc. Conference. Cambridge, MA: The Society of Imaging Science and Technology, May 9-14 1993, pp. 50–52, iSBN: 0-89208-171-6.

[6] P. E. Debevec and J. Malik, "Recovering high dynamic range radiance maps from photographs," SIGGRAPH, pp. 369–378, 1997.

[7] S. Kang, M. Uyttendaele, S. Winder, and R. Szeliski, "High dynamic range video," ACM Trans. Graphics (Proc. SIGGRAPH 2003), vol. 22(3), pp. 319–325, 2003.

[8] E. Khan, O. Akyuz, and E. Reinhard, "Ghost removal in high dynamic range images," ICIP, pp. 2005–8, 2006.

[9] M. Robertson, S. Borman, and R. Stevenson, "Estimation-theoretic approach to dynamic range enhancement using mult. exposures," J. Electronic Img., vol. 12(2), pp. 219–228, 2003.

[10] S. Mann, Intelligent Image Processing. John Wiley and Sons, November 2 2001, iSBN: 0-471-40637-6.