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ORIGINAL RESEARCH PAPER

A real-time implementation of gradient domain high dynamic range compression using a local Poisson solver

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Abstract This paper presents a real-time hardware implementation of a gradient domain dynamic range compression algorithm for high dynamic range (HDR) images. This technique works by calculating the gradients of the HDR image, manipulating those gradients, and reconstructing an output low dynamic range image that corresponds to the manipulated gradients. Reconstruction involves solving the Poisson equation. We propose a Poisson solver that utilizes only local information around each pixel along with special boundary conditions, and requires a small and fixed amount of hardware for any image size, with no need to buffer the entire image. The hardware implementation is described in VHDL and synthesized for a field programmable gate array (FPGA) device. The maximum operating frequency achieved is fast enough to process high dynamic range videos with one megapixel per frame at a rate of about 100 frames per second. The hardware is tested on standard HDR images from the Debevec library. The output images produced have good visual quality.

Keywords Gradient domain dynamic range compression · Tone mapping operator · Poisson equation · Real time · Embedded hardware

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Abbreviations

HDR	High dynamic range
VHDL	VHSIC hardware description language
VHSIC	Very high scale integrated circuit
FPGA	Field programmable gate array
TMO	Tone mapping operator
FFT	Fast Fourier transform
PSNR	Peak signal-to-noise ratio

List of symbols

i, j	Indices used for pixels in full-size images; $i = 0, 1, 2,\ldots,N-1$ and $j = 0, 1, 2,\ldots,N-1$
I^k	The input image and its scale versions (for $k = 0, 1, 2, 3, 4$), each full-size. I^0 is the log-luminance high dynamic range input image, and the scale versions are each produced by applying a 2D approximate Gaussian filter to the input image
I^{out}	The full-size output image, a low dynamic range version of the input
u, v	Indices used for pixels in local windows and gradient matrices. A local window is cut out around a particular pixel (i, j) in the full-size inputs
$\mathcal{I}^k$	Local (6 × 6) windows extracted from the full-size input and scale images (for $k = 0, 1, 2, 3, 4$). Indices are $u = -1, 0, 1, 2, 3, 4$ and $v = -1, 0, 1, 2, 3, 4$
$\mathcal{I}^{out}$	The (6 × 6) local output window produced in one step of the local method. Indices are $u = -1, 0, 1, 2, 3, 4$ and $v = -1, 0, 1, 2, 3, 4$. Given that the windows are extracted around pixel (i, j) in the full-size input and scale images, pixel (2, 2) from this output image is pixel (i, j) in the full-size output image I^{out}