Soft Proofing of Multi-Color Documents in a Panoramic Environment Using Real Time Spectral Processing

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Abstract

*Color management through ICC Profiles has become common place for soft proofing, where CMYK images are transformed through 4-dimensional lookup tables from CMYK to CIE-L*a*b*, then through the system's monitor profile to calibrated RGB. When more than 4 colors are used it becomes impractical to print n-dimensional targets for n-dimensional ICC profiles and the n-dimensional lookup tables for device space to profile connection space in these profiles become extremely coarse. The latest generation of graphic cards contain highly parallelized processors (GPU) which can now be programmed through high level languages like Cg or GLSL. This paper describes a GPU based approach which combines 4-dimensional interpolation for CMYK with a spectral mixing model for n additional colors.*

CMYK -> Spectrum

Spectral CPU based interpolation creates an equally spaced 4-color grid with 31 band spectral wavelength entries. This table becomes the input for the GPU based 4-dimensional interpolation which yields a spectrum describing a CMYK mixture. This will achieve a very low deltaE for colors that contain CMYK exclusively if a traditional CMYK target was printed and spectrally measured. If that was not the case the spectral mixing model described next can also be used for the first 4 colors.

Additional Inks

A spectral mixing model based on spectrally measured individual color ramps predicts the overlay of n additional colors. Since the mixing model does not use any 2 or more color overprints it provides a practical solution to the n-color simulation problem. It is programmed in GLSL, a C like language, and can therefore be replaced easily with similar algorithms (e.g. Kubelka-Munk, Neugebauer, etc.)

Angle Dependency

We simulate a full 3-D environment where an object of arbitrary shape (flat page, printing drum, product packaging), onto which the document is attached, appears in the center of a panoramic environment with user-controllable transforms for object and camera. 3-D units falling out of this geometry like the angle between observer and light source, under further influence of the object's micro-geometry, go into our computation and are computed on a per-pixel basis. Color patches can be measured using a multi-angle spectrometer (e.g. X-Rite MA68, which measures separate spectra at 15, 25, 45, 75 and 110 degrees), thus adding this angle as an additional dimension to our system.

A viewing angle-dependent CMYK spectrum is obtained through a 5-dimensional linearly-interpolated lookup into a fixed-space table which is indexed by the individual process colors and the angle between observer and dominant light direction. A total of 32 spectra are filtered to result in one output CMYK spectrum.

Spectrally-defined spot colors, which are also angle-dependent, are combined with this spectrum before conversion of the blending result from spectral wavelengths to CIE-XYZ, and further conversion through the system's monitor profile.

GPU Optimization

This paper details aspects of the implementation that realize speed improvements of an order of magnitude, in comparison to a straightforward implementation, by choosing data types and structures that play to the strengths of the GPU hardware. We obtain filtered data throughput in excess of 10 GB/s, which represents a roughly 10x speed improvement in comparison to an optimized vector-unit-based (SSE2, AltiVec) CPU implementation, and on the order of two magnitudes faster speed compared to plain C/C++ code running on a modern CPU.

Figure 1. Rendering of 8-color document.