Superimposing Dynamic Range

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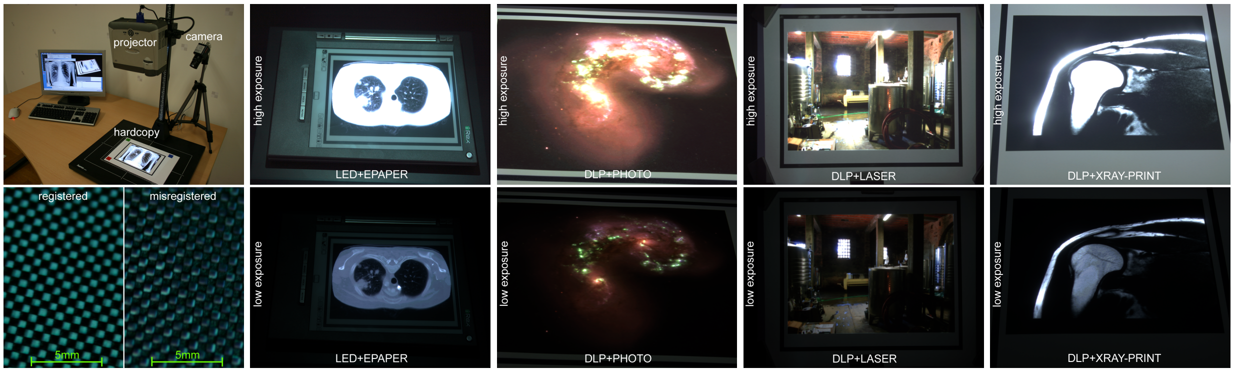

Figure 1: *Registering a projector precisely to a hardcopy allows extending contrast, perceivable tonal resolution and color space beyond the capabilities of either hardcopy or projector. From left to right: experimental setup and example for achieved registration precision (projected checker on printed checker with a field size of 0.62 mm – or 7 cycles per degree (cpd) at 50 cm viewing distance), low and high exposure photographs of different hardcopies (ePaper display, photographic print, laser print and X-ray print) amplified with LED and DLP projectors.*

1 Introduction

It was only recently that high dynamic range (HDR) displays were introduced which could present content over several orders of magnitude between minimum and maximum luminance (e.g., [Seetzen et al. 2004]). All of the approaches share three common properties: These are firstly that they apply a transmissive image modulation (either through transparencies or LCD/LCoS panels) and consequently suffer from a relatively low light-throughput (e.g., regular color / monochrome LCD panels transmit less than 3-6% / 15-30% of light) and therefore require exceptionally bright backlights. Secondly, one of the two modulation images is of low-resolution and blurred in order to avoid artifacts such as moiré patterns due to the misalignment of two modulators, as well as to realize acceptable frame-rates. Thus, high contrast values can only be achieved in a resolution of the low-frequency image. Thirdly, since one of the two images is monochrome (mainly to reach a high peak luminance), only luminance is modulated, while chrominance modulation for extending the color space is in some cases considered future work. We present a simple and low-cost method of viewing static HDR content based on reflective image modulation.

2 Superimposing Dynamic Range

We project images onto hardcopies, such as photographs, X-ray prints, or electronic paper (ePaper) so as to boost contrast, perceivable tonal resolution, and color space values beyond the potential of either hardcopies (when viewed under environment light) or projectors (when projecting onto regular screens) alone. A calibrated projector-camera system is applied for automatic registration, scanning and superimposition of hardcopies. Figure 1 illustrates examples thereof. We do not intend to compete with interactive HDR displays, but rather offer an "everybody can do" alternative for domains that operate with static image content, such as radiology and other medical fields, or astronomy. Yet, electronic paper allows for interactive visualizations.
In our experiments, we achieved contrast ratios of over 45,000:1 with a peak luminance of more than 2,750 cd/m^2, could technically re-produce more than 620 perceptually distinguishable tonal values (approximately 85% of all theoretically possible JND steps). Furthermore, we attained color space extensions of up to factor 1.4 (compared to a regular projections) or factor 3.3 (compared to regular hardcopy prints). Thereby, the hardcopy resolution can be several thousand dots per inch, while luminance and chrominance are modulated with a registration error of less than 0.3 mm.

3 Discussion

Compared with most existing interactive HDR displays, we support near distance viewing at a contrast resolution of up to 7 cpd (given our current registration precision and assuming a viewing distance of 50 cm). Due to scattering of light in the eye, the perceived local contrast is reduced, depending mainly on the adaptation luminance and on the spatial frequency of the observed content. Referring to the optical transfer function of the eye described in [Mantiuk et al. 2005], we can still achieve a perceived local contrast of 40%-69% at a spatial resolution of 7 cpd and an adaptation luminance of 0.06 cd/m^2 - 2,750 cd/m^2. It is also reported in [Mantiuk et al. 2005] that the contrast sensitivity (CS) for an adaptation luminance above 1,000 cd/m^2 is maximal at this resolution, and that the CS-peak only shifts to lower frequencies with a decreasing adaptation luminance. We believe that our approach has the potential to complement hardcopy-based technologies, such as X-ray prints for filmless imaging, in domains that operate with high quality static image content, like radiology and other medical fields, or astronomy.

References

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SIGGRAPH 2008, Los Angeles, California, August 11–15, 2008.
ISBN 978-1-60558-466-9/08/0008