Supplementary Material:
Correcting for Optical Aberrations using Multilayer Displays

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This document contains additional results and implementation details. Appendix A illustrates the prototype construction. Appendix B further assesses the benefits and limitations of multilayer pre-filtering, compared to prior single-layer pre-filtering methods, as introduced by Alonso and Barreto [2003] and Yellott and Yellott [2007].

A Construction of the Multilayer Display Prototype

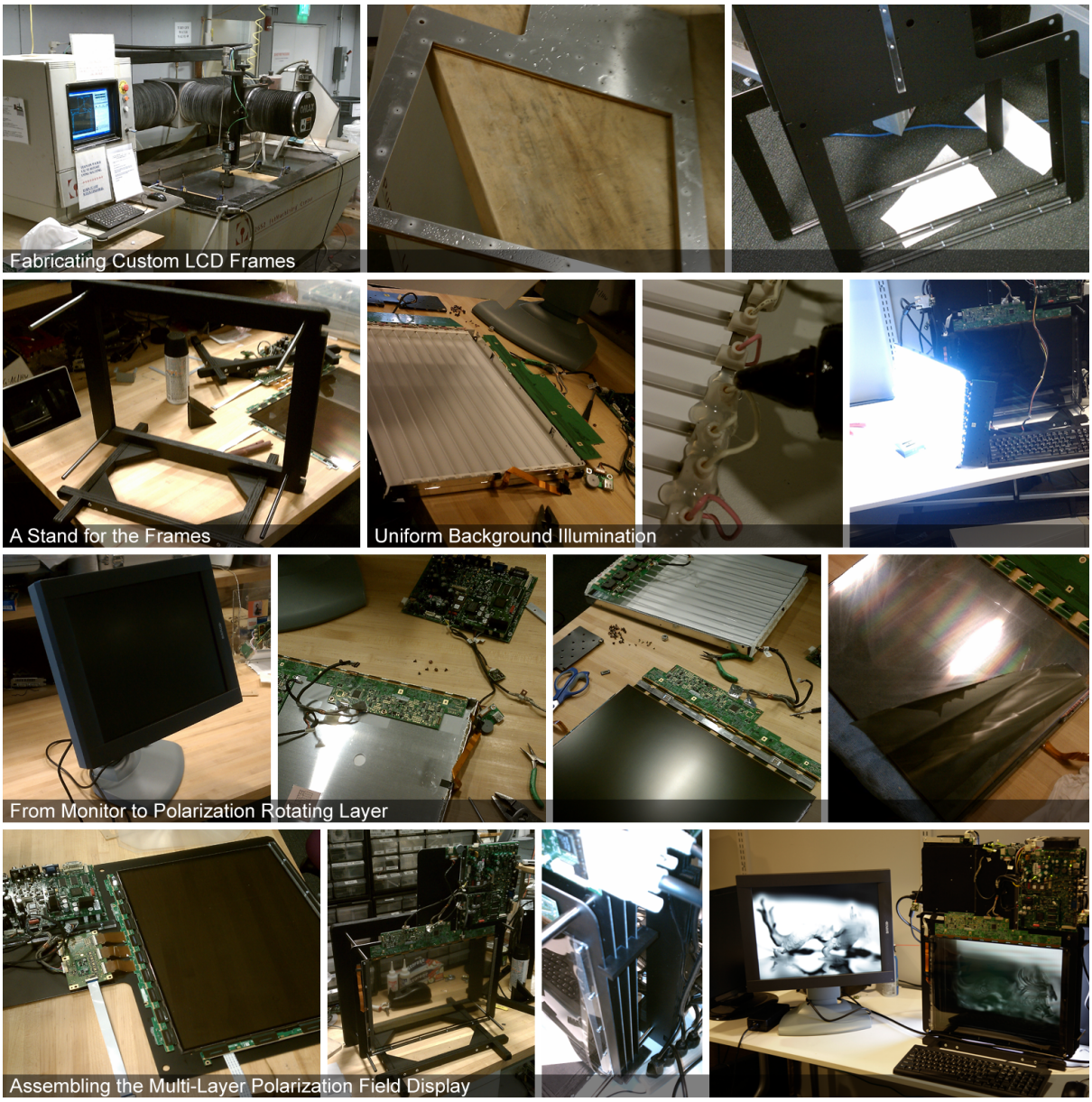

Figure S.1: *Prototype construction. Four monochrome, off-the-shelf medical LCDs were modified. Polarizing films were removed and electronics repositioned so the panels could be mounted on custom-fabricated frames. The layers are separated by acrylic spacers and illuminated by a uniform backlight, following Lanman et al. [2011].*

B Additional Results

B.1 Comparing Single-Layer and Multilayer Pre-filtering with "Equalized" Display Brightness

In this supplement, we have "equalized" the received image brightness for several figures in the primary text. The first row of Figure S.2 shows the received images, as is depicted in Figure 4 in the manuscript. The multilayer pre-filtered image shown in second row is dimmed to the level of the image received using single-layer pre-filtering. Note that multlayer pre-filtering exhibits increased dynamic range and greater contrast; also note that Michaelson contrast does not change due to dimming (i.e., due to multiplication by a constant). On the third row, the single-layer pre-filtering result is brightened such that the maximum brightness equals that obtained with multilayer pre-filtering. Again, the dynamic range and contrast are greater with multilayer pre-filtering.

Multilayer pre-filtering not only improved legibility, but also preserves all spatial frequencies to eliminate ringing artifacts. In the lower-left of Figure S.2, we show how certain spatial frequencies were lost with single-layer pre-filtering, due to nulls in the modulation transfer function (MTF), resulting in ringing artifacts. In this example, we highlight this effect by depicting a "non-physical" display capable to emitting optical rays with both positive and negative radiance (i.e., eliminating the need for normalization). Figure S.3 provides a similar comparison for Figure 6 from the primary text.

B.2 Comparing Deconvolution Methods

We also assess the performance of single-layer pre-filtering, relative to multilayer pre-filtering, with different choices for the underlying deconvolution method. Figure S.4 tabulates the perceived images, again assuming a "non-physical" display emitting rays with both positive and negative radiance. The first column tabulates the results obtained using Richardson-Lucy deconvolution [Gonzalez and Woods 1992]. Note the severe ringing artifacts . The second column tabulates the results obtained using the deconvolution method introduced by Levin et al. [2007]. While ringing is reduced, sharp features appear blurred (e.g., the coin and the figures on the bills). Given knowledge of the precise point spread function, Wiener filtering is capable of preserving such features, as shown in the third column. However, with single-layer pre-filtering, certain frequencies cannot be preserved, resulting in ringing artifacts. As shown in the fourth column, multilayer pre-filtering, employing Wiener deconvolution, eliminates ringing and preserves sharp features.

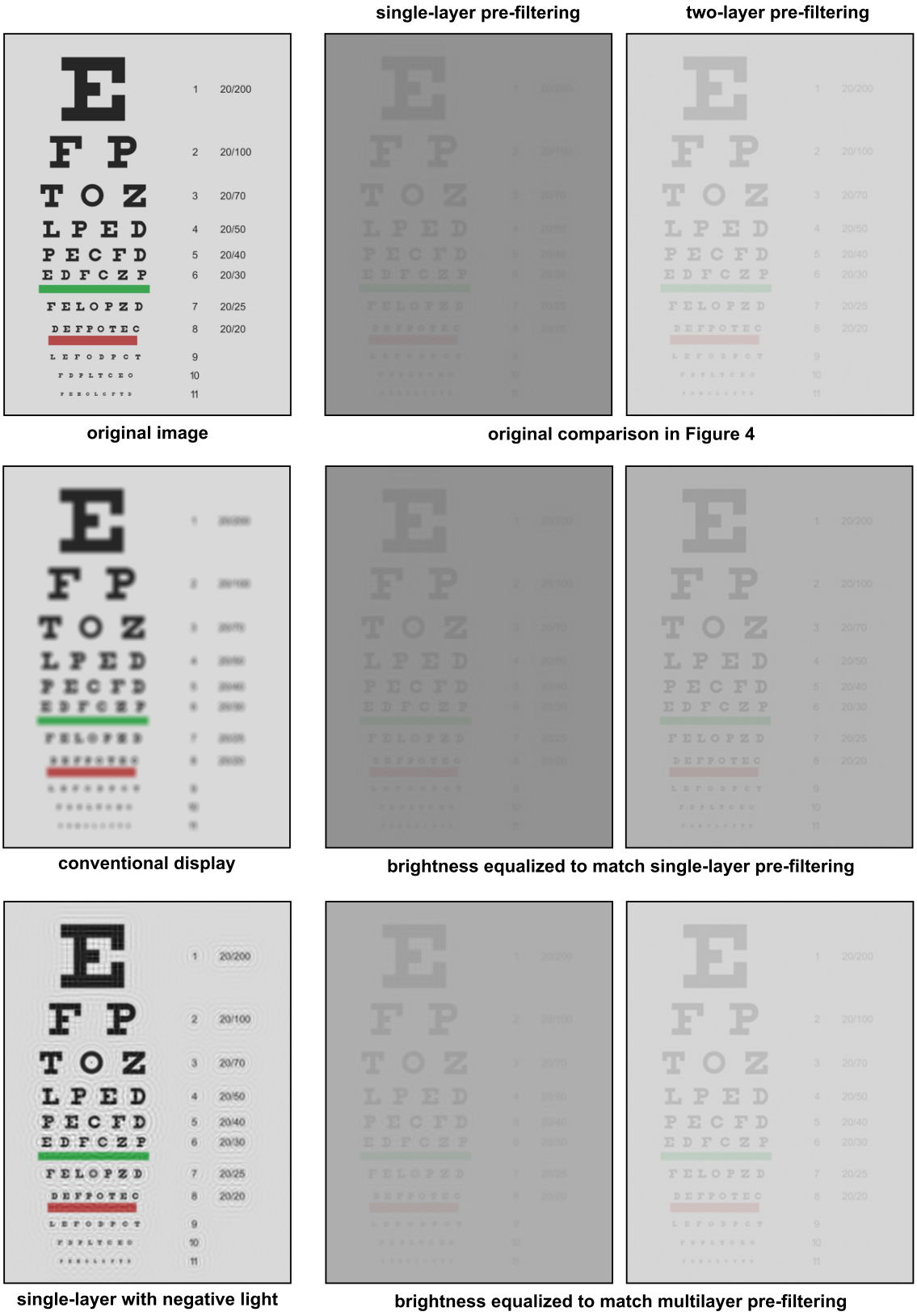

Figure S.2: *Reproduction of Figure 4 from the primary text with the brightness "equalized", assisting in comparison of the the single-layer and multilayer pre-filtered images.*

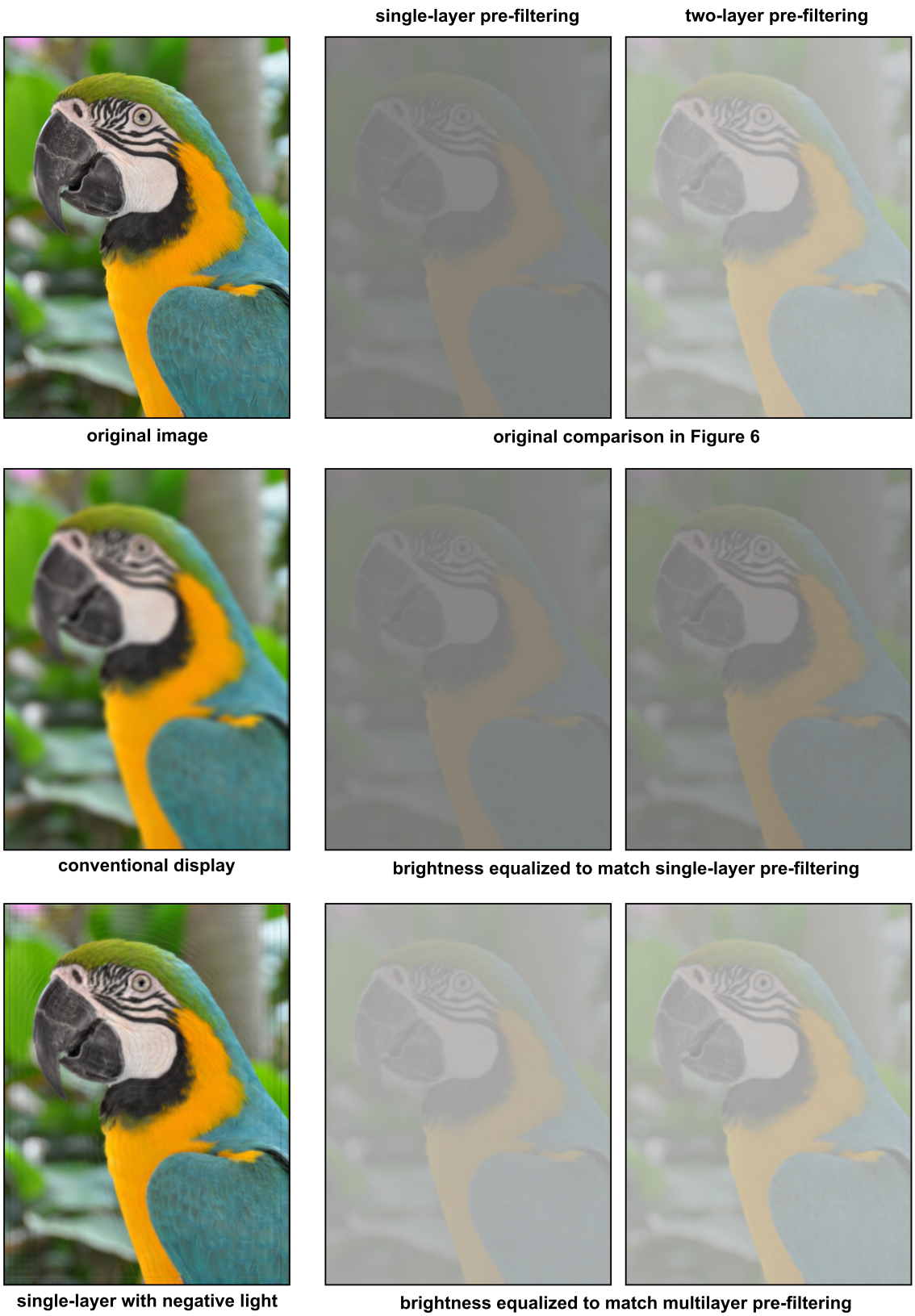

Figure S.3: *Reproduction of Figure 6 from the primary text with the brightness "equalized", assisting in comparison of the the single-layer and multilayer pre-filtered images.*

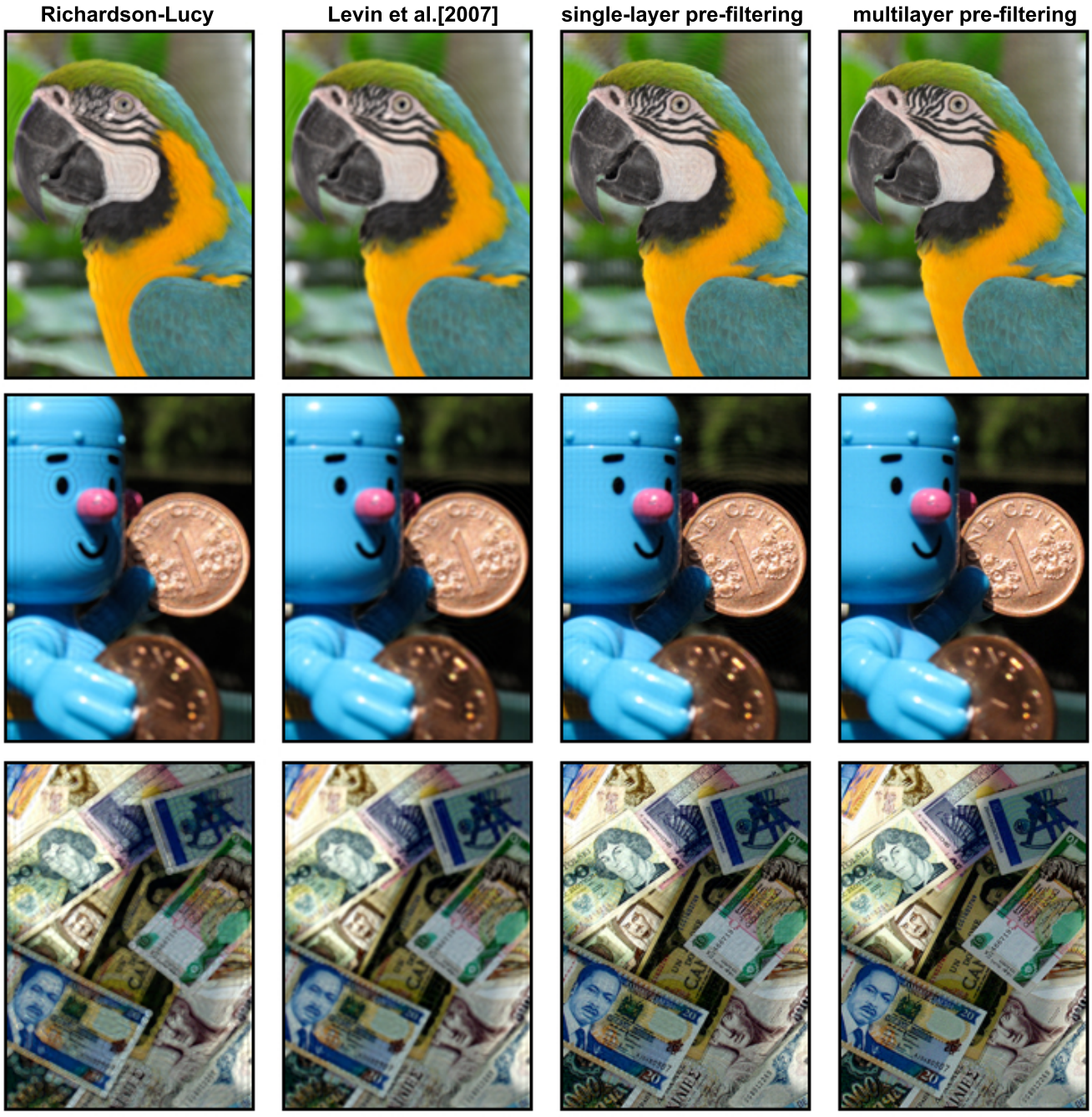

Figure S.4: *Comparison of single-layer deconvolution, using a variety of methods, versus multilayer pre-filtering employing Wiener deconvolution. We assess the relative benefits and limtiation of Wiener filtering, the iterative Richardson-Lucy algorithm [Gonzalez and Woods 1992], and the method introduced by Levin et al. [2007].*

Supplementary References

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