Intrinsic Images in the Wild: Supplemental Material

Sean Bell Kavita Bala Noah Snavely
Cornell University

1 Algorithm variants

Here, we describe some of the algorithm variants described in Table 1 of our paper. These variants either do not help or perform worse than the final algorithm described in the paper.

1.1 Add reflectance prior

In real-world scenes, not all surface colors appear with equal frequency. For example, in indoor scenes, pastel colors and medium grays appear much more frequently than bright neon colors. We can encode this knowledge in our model with a prior on reflectance colors. Specifically, we take all surfaces from OpenSurfaces [Bell et al. 2013] and collect the diffuse reflectance color intensity. Since we have over 40,000 samples, we store the samples in a tabulated probability distribution p_r (a histogram with 100 bins) and blur the counts with $\sigma = 3$ bins. Our energy term is simply the negative log probability:

$$E_r(x) = -\sum_i \log p_r(\mathcal{R}(x_i)) \quad (1)$$

This is similar to the absolute reflectance prior used in SIRFS [Barron and Malik 2013], but with a histogram instead of a spline.

Exploring different weights for this term, the best training error is $\text{WHDR}_{10\%} = 21.0\%$. This is achieved by setting the weight to 0, so we exclude this term. Giving E_r more weight increases the error by a few tenths of a percent.

1.2 Add chromaticity prior

Since we are labeling pixels with RGB reflectances ($\mathcal{R}$), we initially assumed that it would be important to constrain the chromaticity of the reflectance to match that of the input image. This can be encoded in one of two ways: (1) encourage the chromaticity of the chosen label to match its image pixel, or (2) compute a colored RGB shading channel and encourage it to be grayscale. Mathematically, the former is:

$$E_c(x) = \sum_i \left\| \frac{\mathcal{R}(x_i)}{\sum_c \mathcal{R}^c(x_i)} - \frac{\mathbf{I}_i}{\sum_c I_i^c} \right\|_1 \quad (2)$$

A similar term can be written for the latter.

Exploring different weights for this term, the best training error (excluding zero weight) is $\text{WHDR}_{10\%} = 21.1\%$. This is achieved by setting the weight as small as possible, so we exclude this term. Giving E_c more weight increases the error.

1.3 Equation 19: Different window sizes

In Equation 19, we only constrain neighboring pixels to have similar shading. We tried expanding the set B by connecting pixels in wider windows, such as connecting pixels k above/below and k left/right. We also tried downweighting longer connections by $1/d_{ij}^2$ where d_{ij} is the distance between pixels i and j.

We find that increasing the window size makes no change (but makes the algorithm run much slower), as long as we downweight connections by $1/d_{ij}^2$. Using the same weight for all types of connections increases the error.

1.4 Other variants

The remaining variants are smaller changes and described in Table 1 of the paper. For example, we experimented with both L^1 and L^2 norms for most terms. We varied every parameter including the number of iterations. We tried different initialization methods, such as initializing the shading channel with the input image, with the solution from Retinex, with a constant, and by omitting the term. We tried deleting different energy terms and removing the final cluster splitting step (Stage 2, Section 4.3 of the paper).

2 Validation: Varying lighting conditions

As discussed in the paper (Section 3.6), we further validated our judgements using 11 photographs across 4 scenes from [Boyadzhiev et al. 2013]. These scenes have with identical camera viewpoint and varying lighting conditions, so any disagreement in judgements between the different viewpoints is incorrect in at least one of the photos. The scenes are shown in Figure 1 and included on our website (`http://intrinsic.cs.cornell.edu`). Experimental results are included in the paper (Section 3.6).

3 Additional visual comparisons

Figures 2 through 101 show example visual comparisons between our algorithm and [Zhao et al. 2012], [Garces et al. 2012], Retinex [Grosse et al. 2009], and [Shen et al. 2011].

The photos are sorted by decreasing number of judgements, so these are the 100 best sampled photos in terms of human judgement.

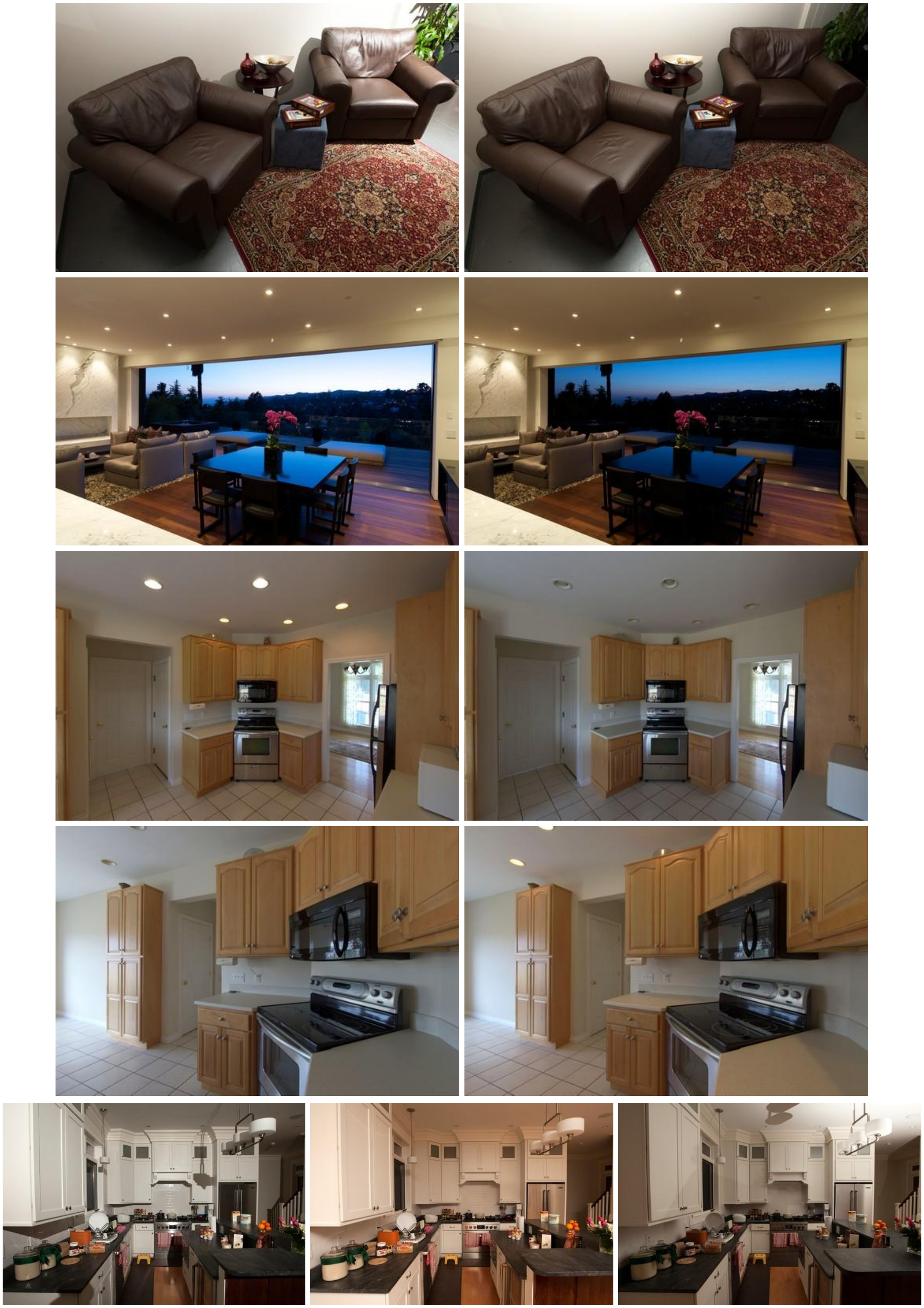


Figure 1: *Scenes with identical viewpoint but varying lighting conditions [Boyadzhiev et al. 2013]. The photos in the second row are provided by a professional photographer (© Michael Kelley).*

Figure 2: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 16594.*

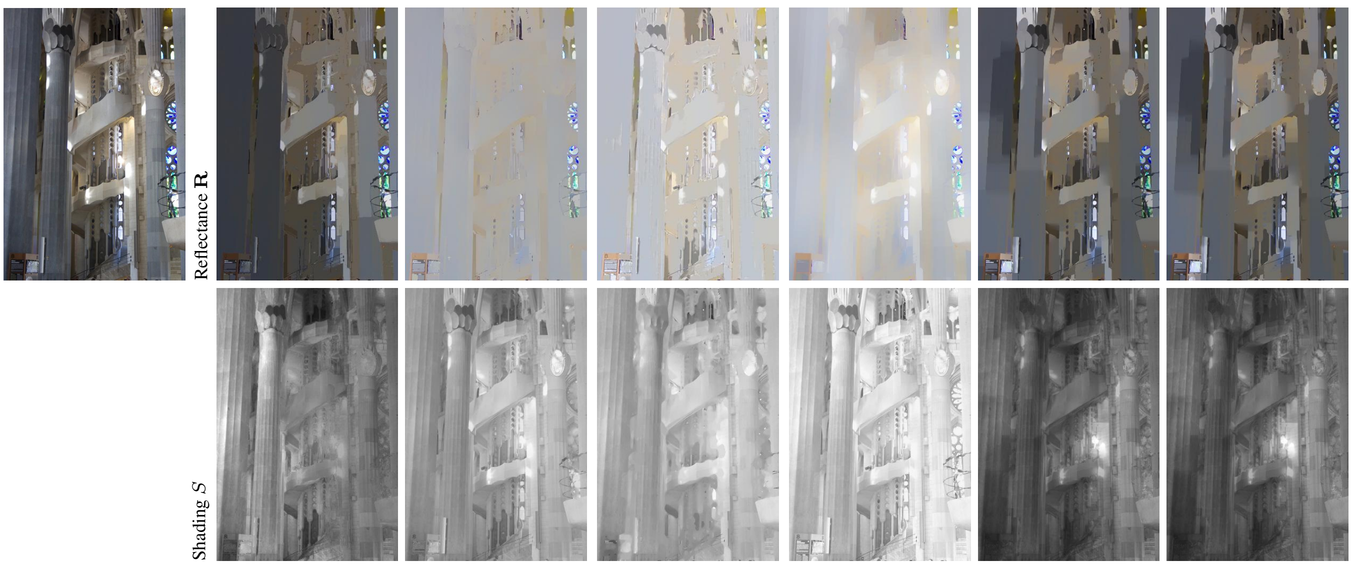


Figure 3: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 22774.*

Figure 4: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 83120.*

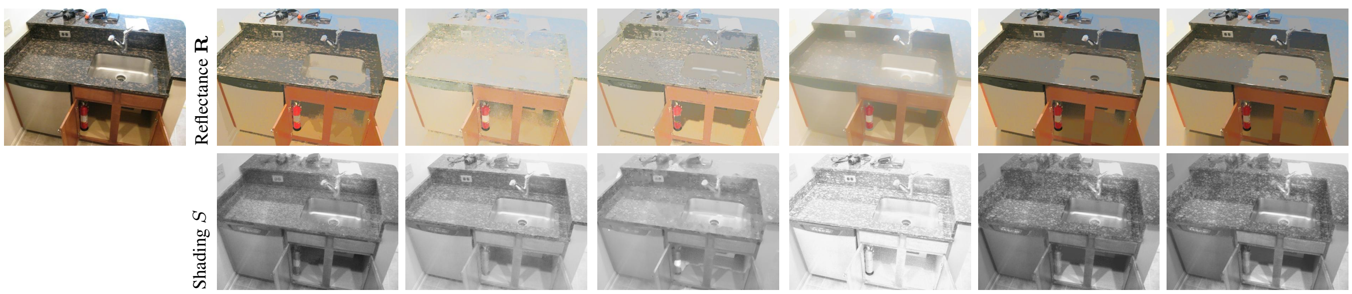
Figure 5: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 109510.*

Figure 6: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 85613.*

Figure 7: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 56756.*

	WHDR = 9.2%	8.3%	18.6%	13.7%	11.3%	11.4%
Image **I**	Our algorithm	[Zhao et al. 2012]	[Garces et al. 2012]	[Shen et al. 2011]	Retinex (gray)	Retinex (color)

Figure 8: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR*$_{10\%}$ *across all photos). OpenSurfaces Photo ID: 3438.*



	WHDR = 31.9%	26.1%	29.7%	34.4%	32.9%	31.4%
Image **I**	Our algorithm	[Zhao et al. 2012]	[Garces et al. 2012]	[Shen et al. 2011]	Retinex (gray)	Retinex (color)

Figure 9: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR*$_{10\%}$ *across all photos). OpenSurfaces Photo ID: 94020.*

	WHDR = 28.5%	18.0%	23.6%	23.7%	28.9%	28.4%
Image **I**	Our algorithm	[Zhao et al. 2012]	[Garces et al. 2012]	[Shen et al. 2011]	Retinex (gray)	Retinex (color)

Figure 10: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR*$_{10\%}$ *across all photos). OpenSurfaces Photo ID: 57242.*

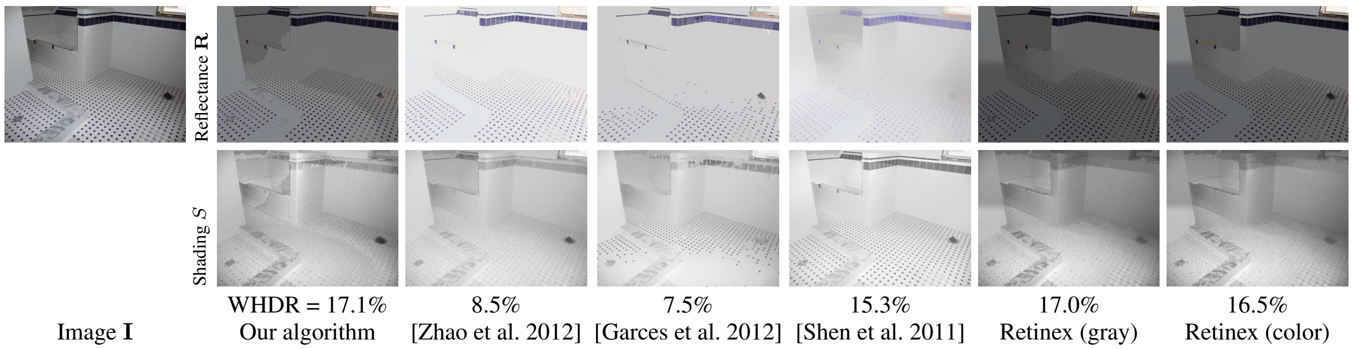


Figure 11: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 6114.*

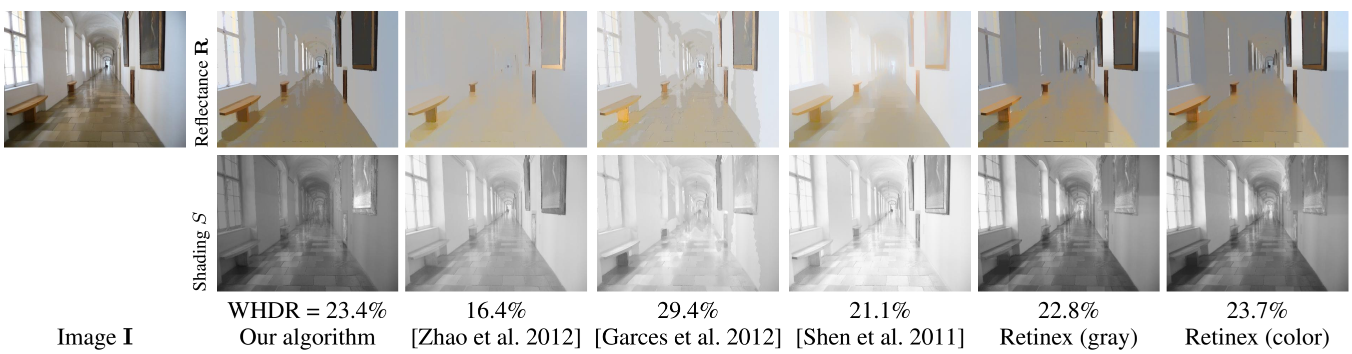


Figure 12: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 108943.*

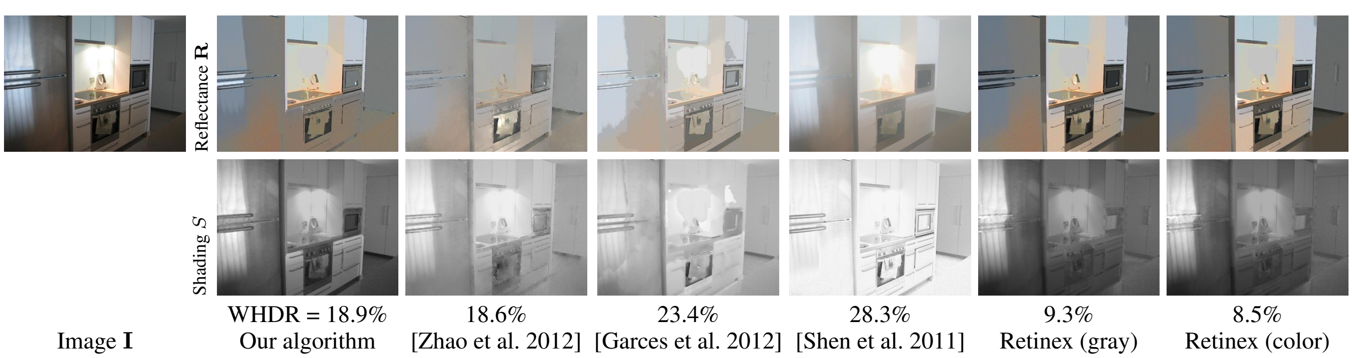


Figure 13: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 83619.*

Figure 14: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathrm{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 97286.*

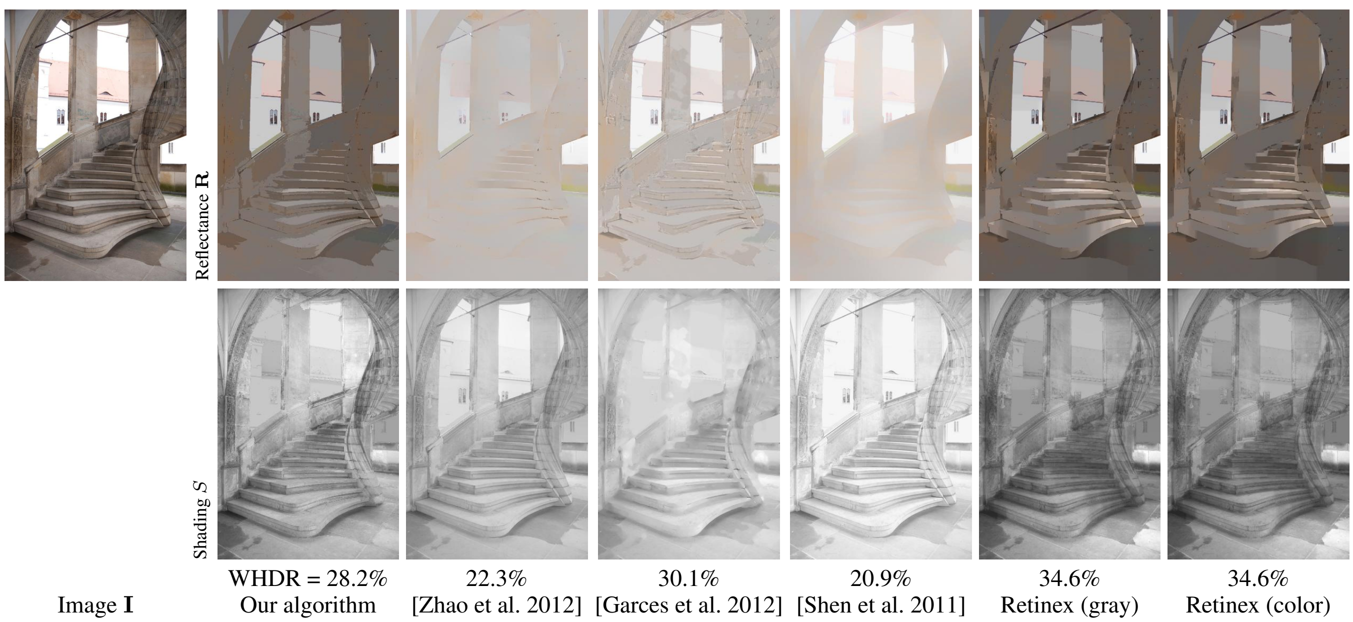


Figure 15: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathrm{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 24537.*

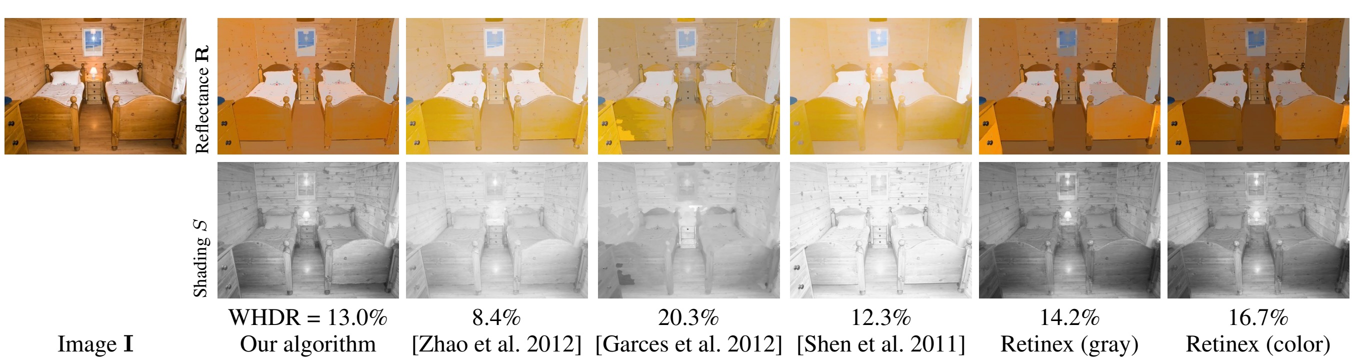


Figure 16: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathrm{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 98173.*

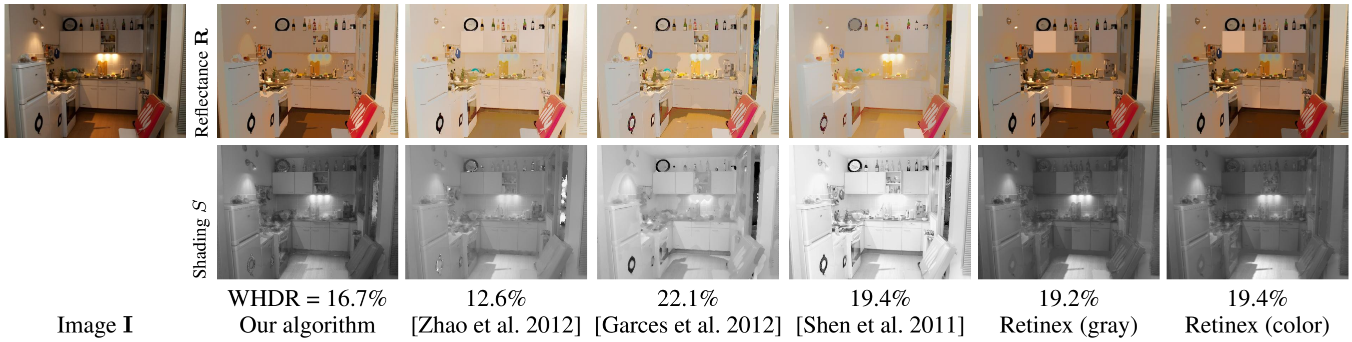


Figure 17: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 82358.*

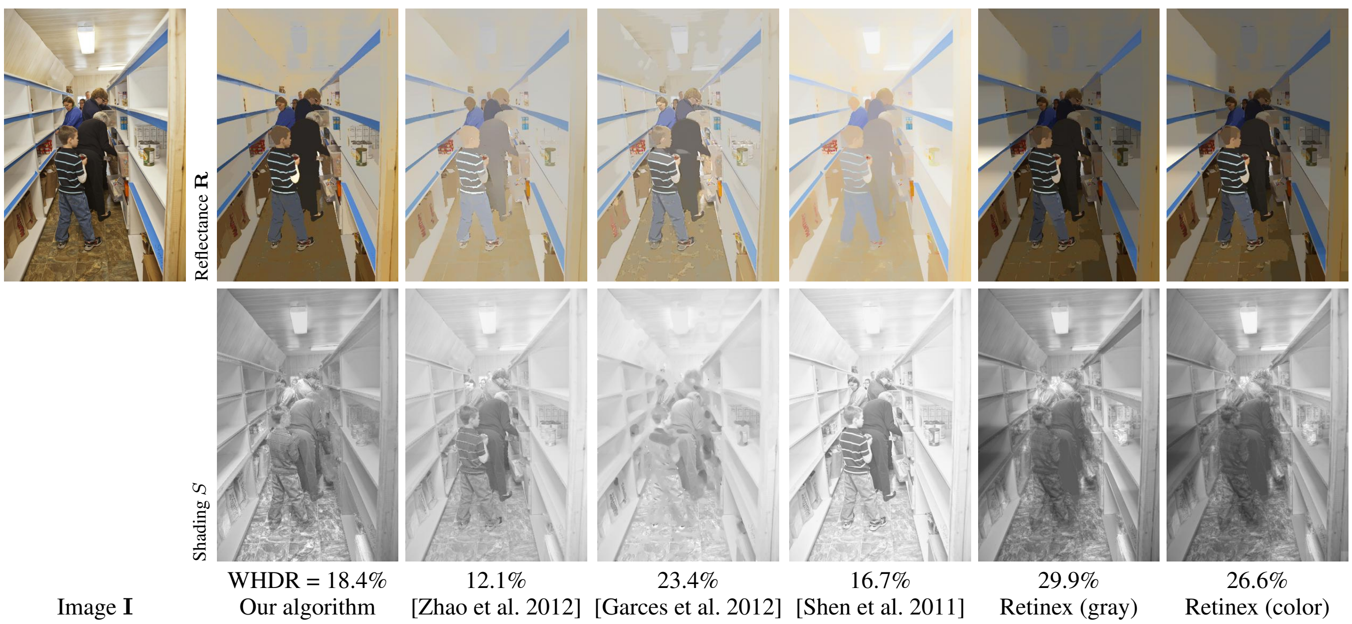


Figure 18: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 55472.*

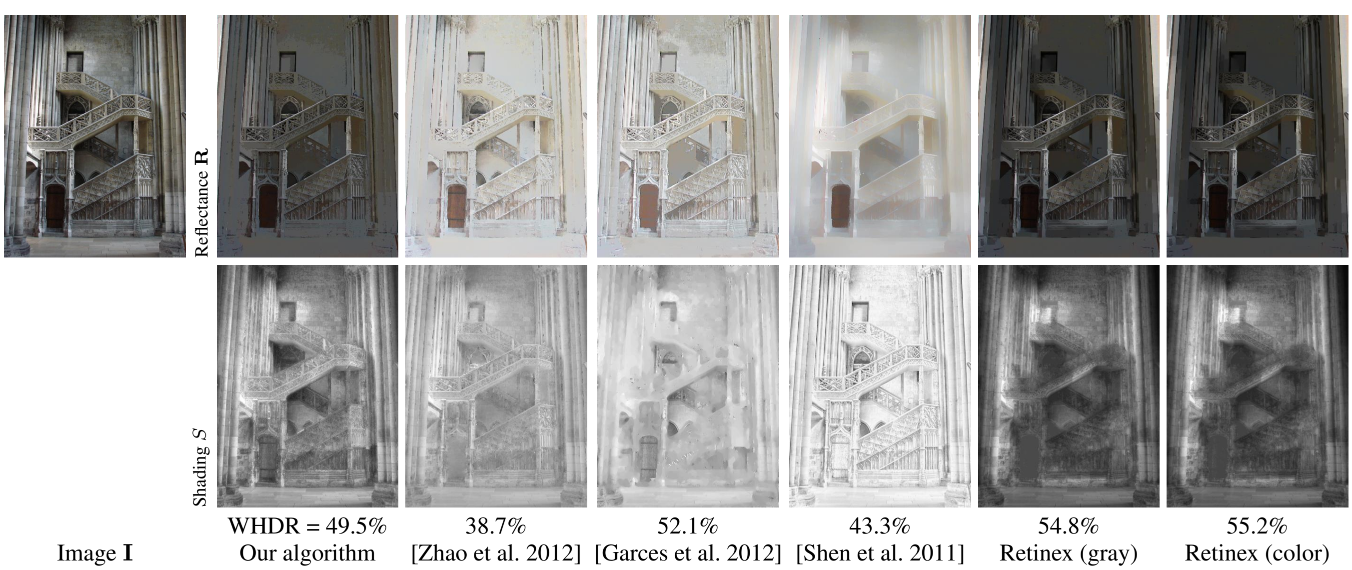


Figure 19: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 22754.*

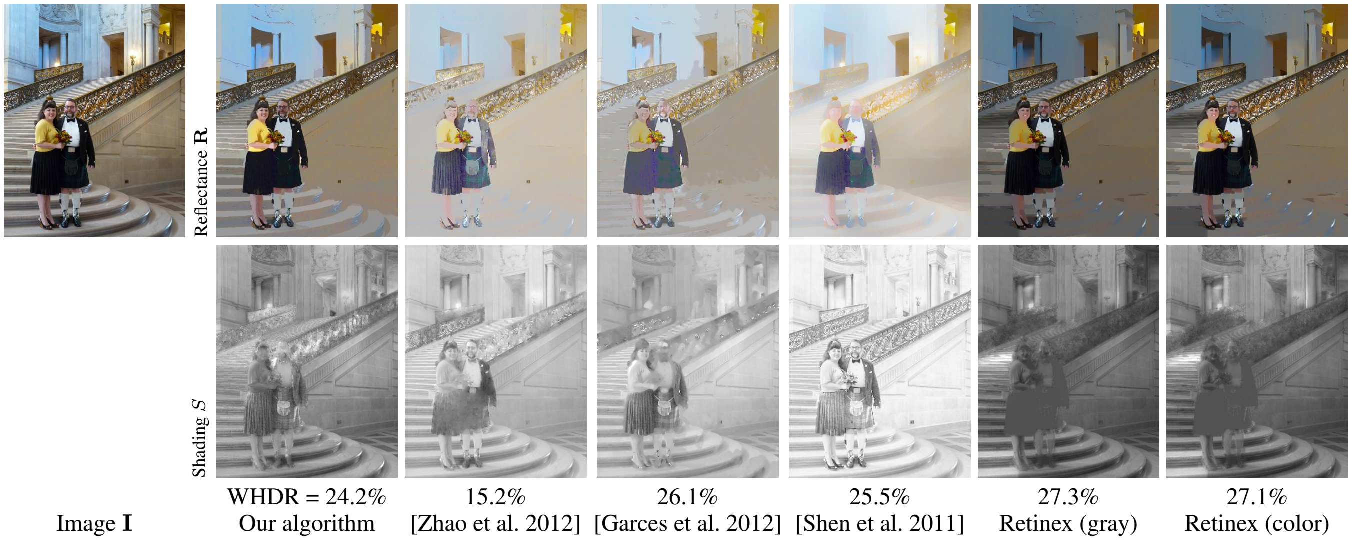


Figure 20: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathit{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 24637.*

Figure 21: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathit{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 88857.*

Figure 22: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $\mathit{WHDR}_{10\%}$ *across all photos). OpenSurfaces Photo ID: 88648.*

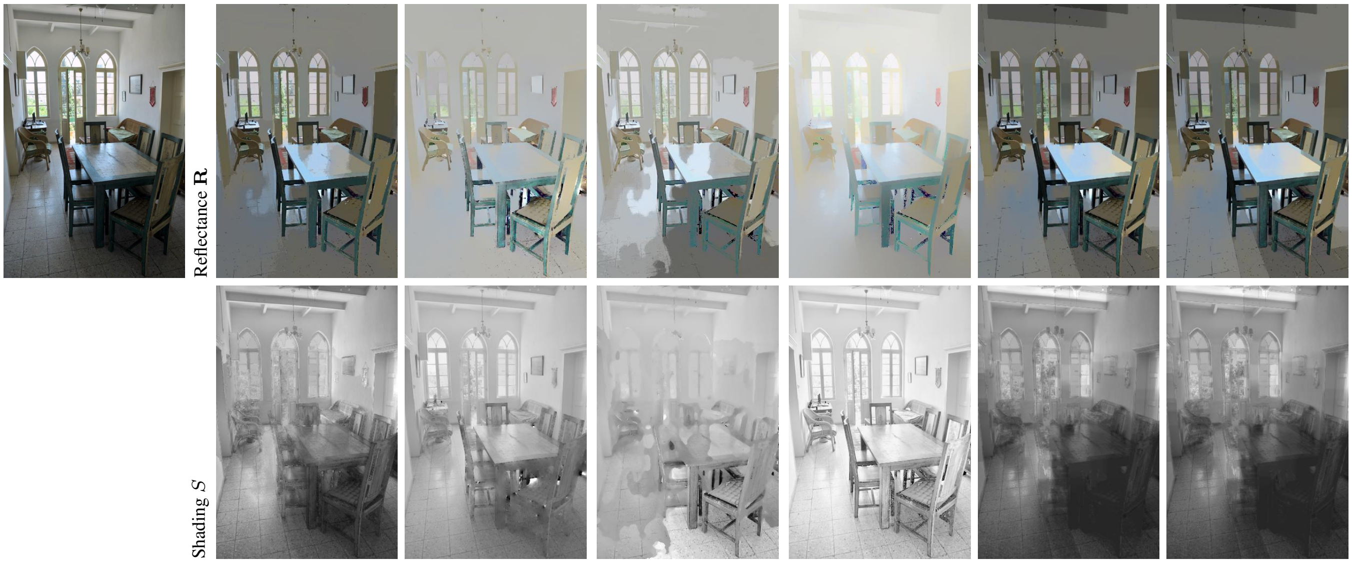


Figure 23: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 89829.*

Figure 24: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 118146.*

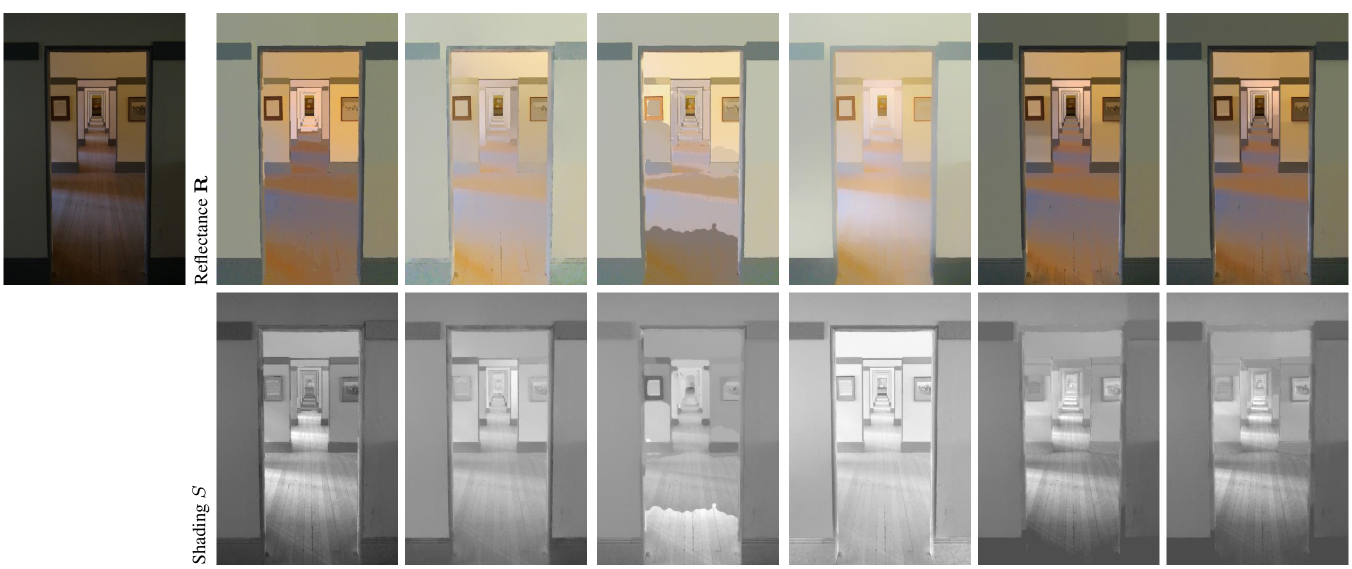


Figure 25: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 108963.*

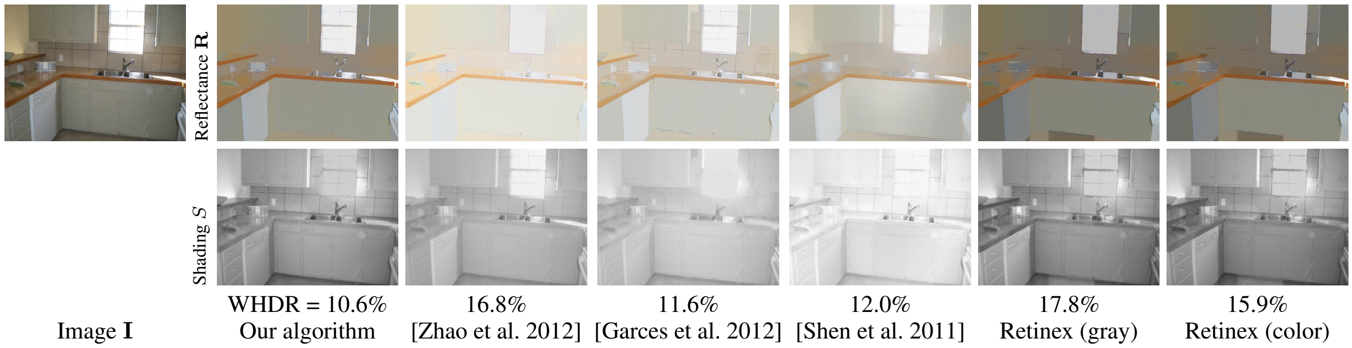


Figure 26: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 84900.*

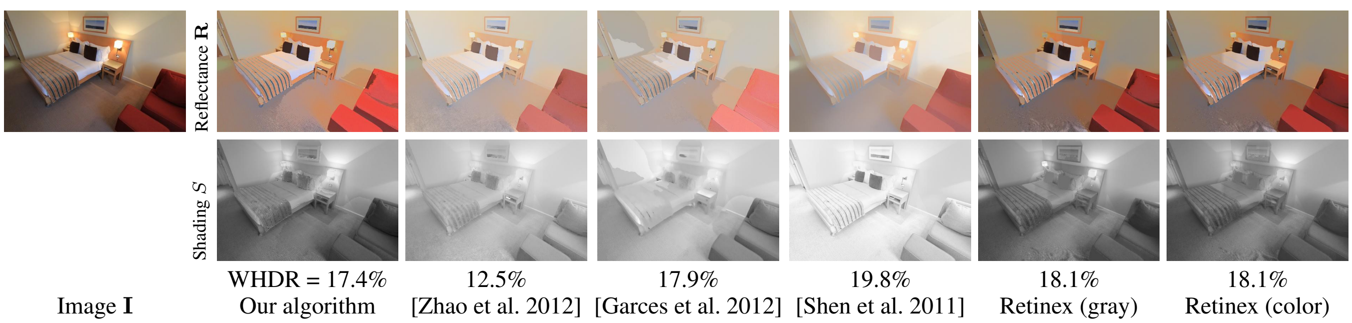


Figure 27: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 97071.*

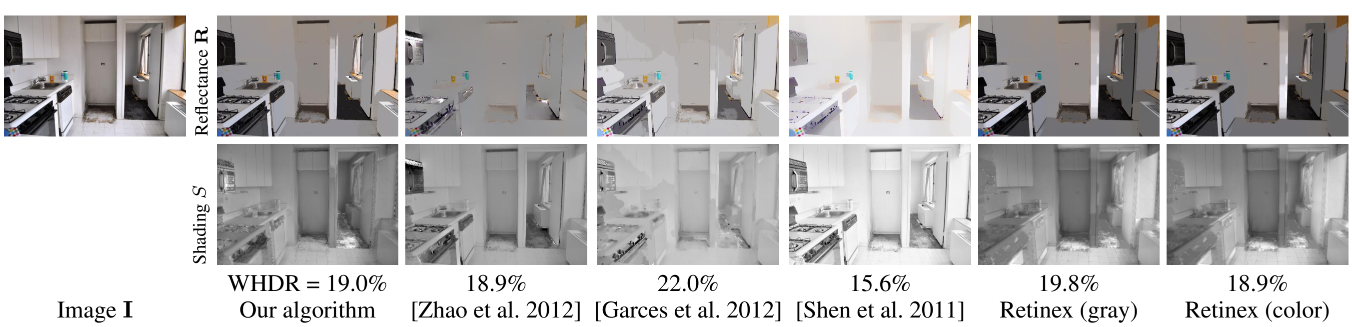


Figure 28: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 85917.*

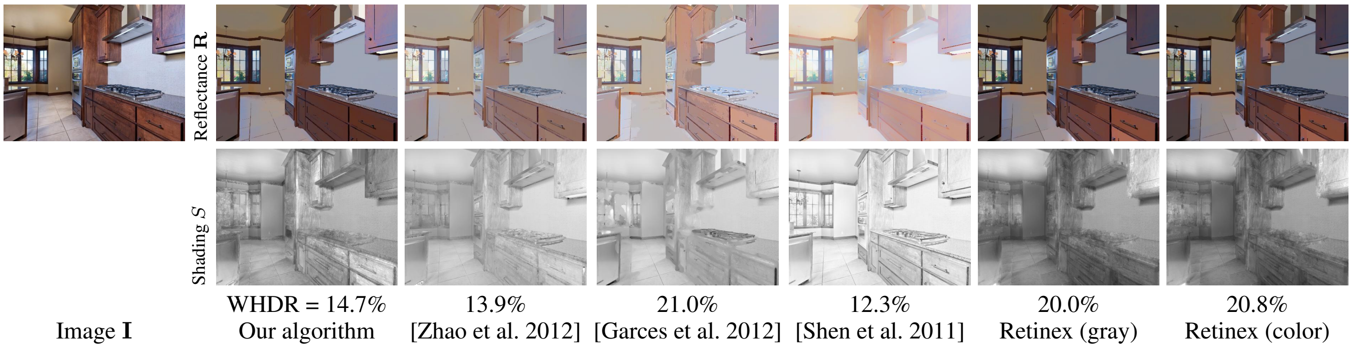


Figure 29: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 116883.*

Figure 30: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 97315.*

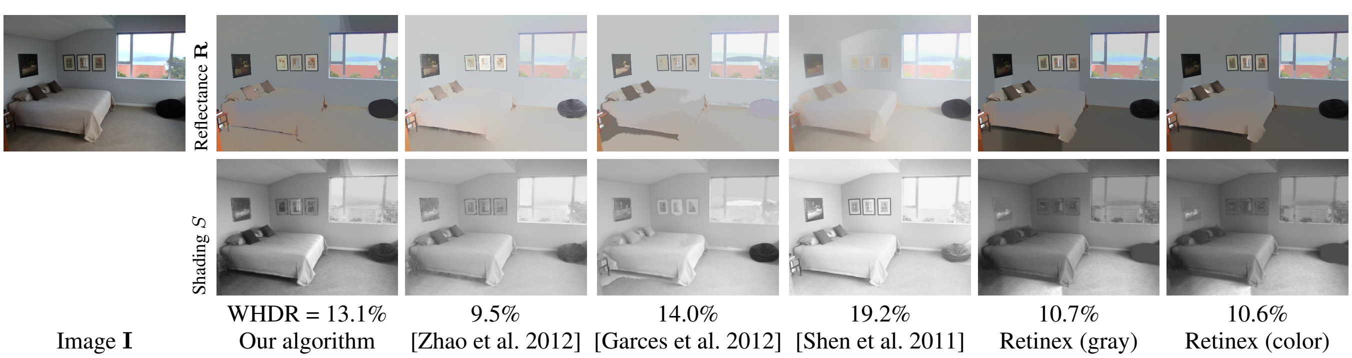


Figure 31: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 101511.*

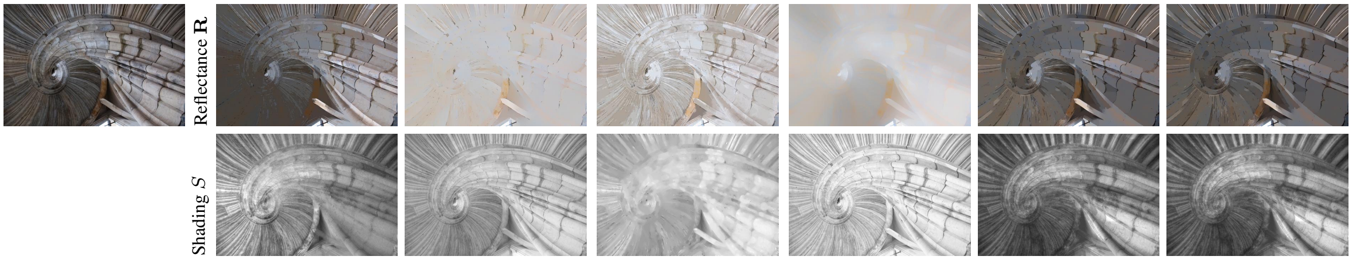


Figure 32: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 23535.*

Figure 33: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 84210.*

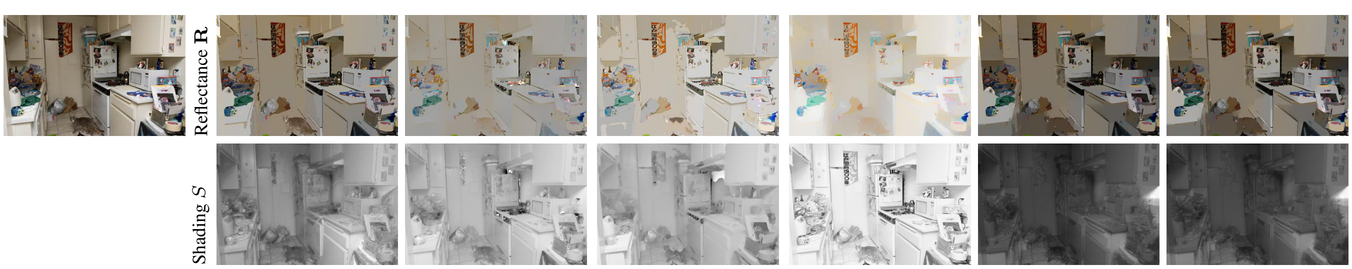


Figure 34: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 87598.*

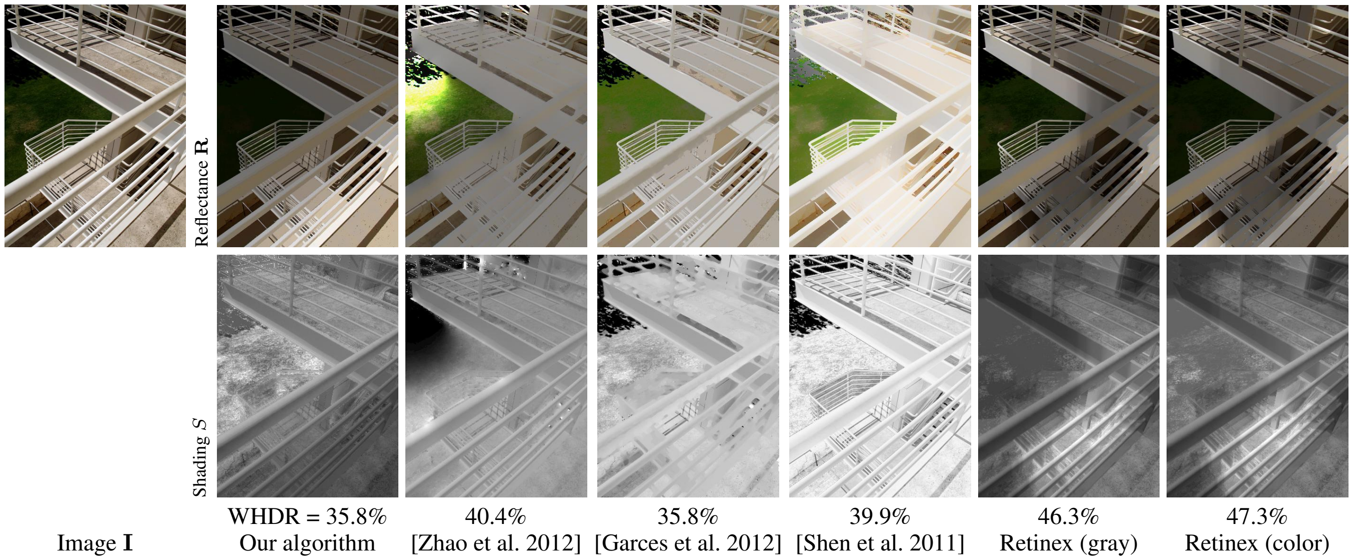


Figure 35: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 26386.*

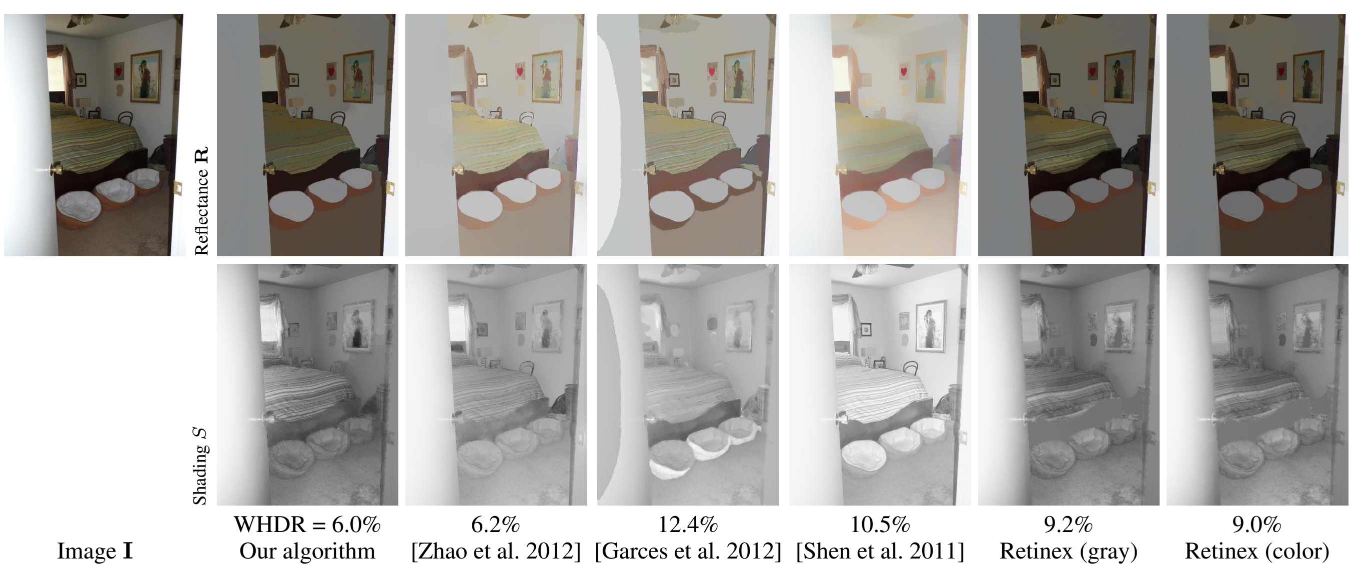


Figure 36: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 100318.*

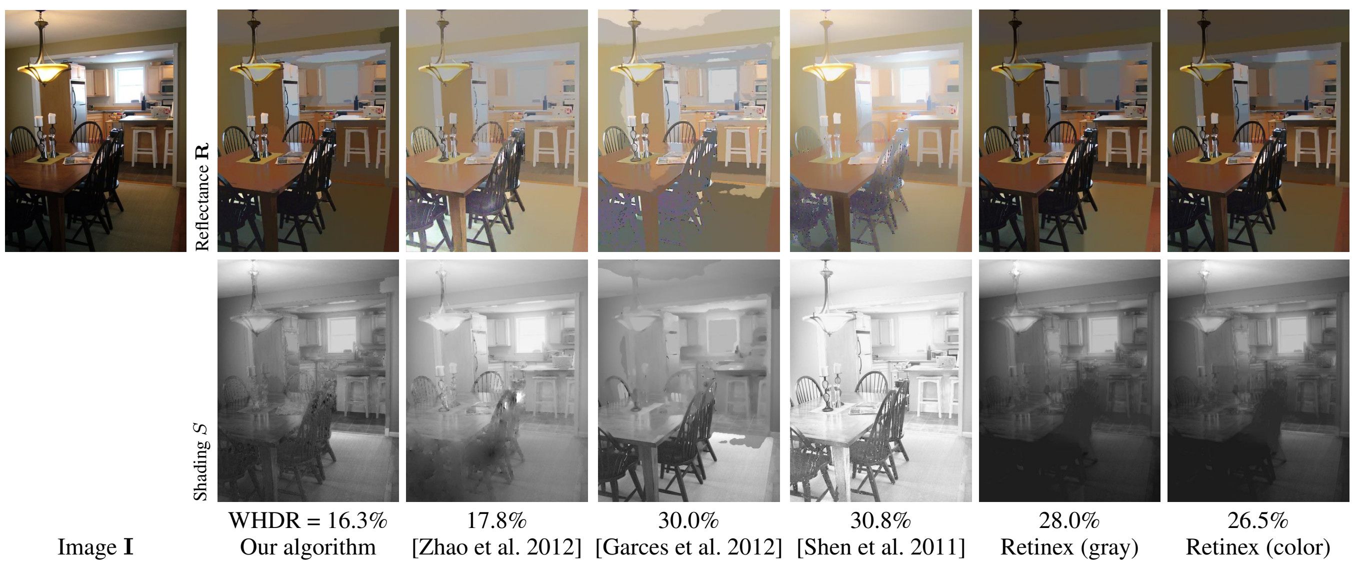


Figure 37: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 11907.*

Image $\mathbf{I}$	WHDR = 22.7% Our algorithm	27.2% [Zhao et al. 2012]	16.4% [Garces et al. 2012]	37.7% [Shen et al. 2011]	23.7% Retinex (gray)	28.1% Retinex (color)

Figure 38: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 100629.*

Image $\mathbf{I}$	WHDR = 24.5% Our algorithm	30.7% [Zhao et al. 2012]	32.6% [Garces et al. 2012]	40.0% [Shen et al. 2011]	23.0% Retinex (gray)	23.4% Retinex (color)

Figure 39: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 74024.*

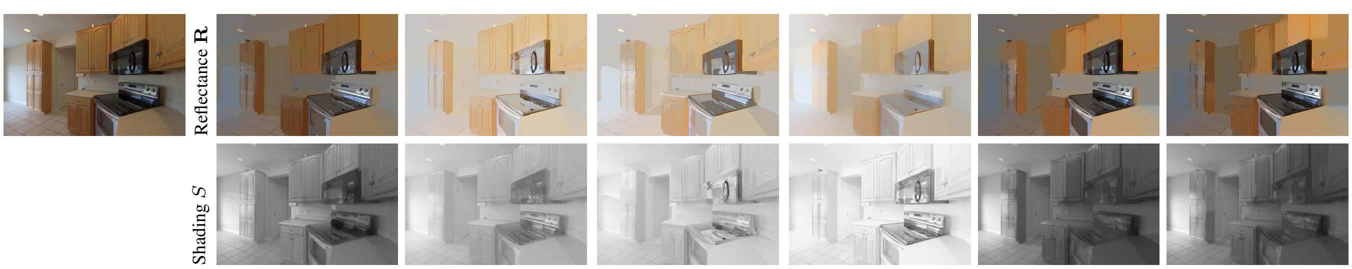


Image $\mathbf{I}$	WHDR = 23.1% Our algorithm	20.8% [Zhao et al. 2012]	20.0% [Garces et al. 2012]	24.3% [Shen et al. 2011]	27.7% Retinex (gray)	30.9% Retinex (color)

Figure 40: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 118512.*

Figure 41: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 83267.*

Figure 42: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 118511.*

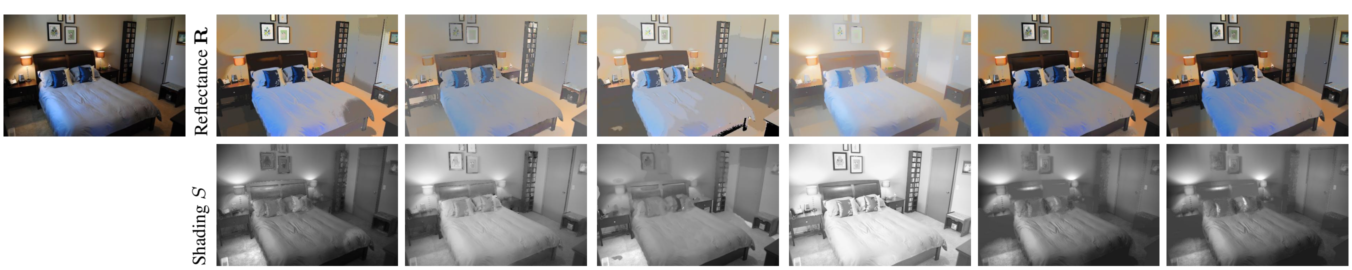


Figure 43: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 97316.*

Figure 44: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 82623.*

Figure 45: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 34942.*

Figure 46: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 105838.*

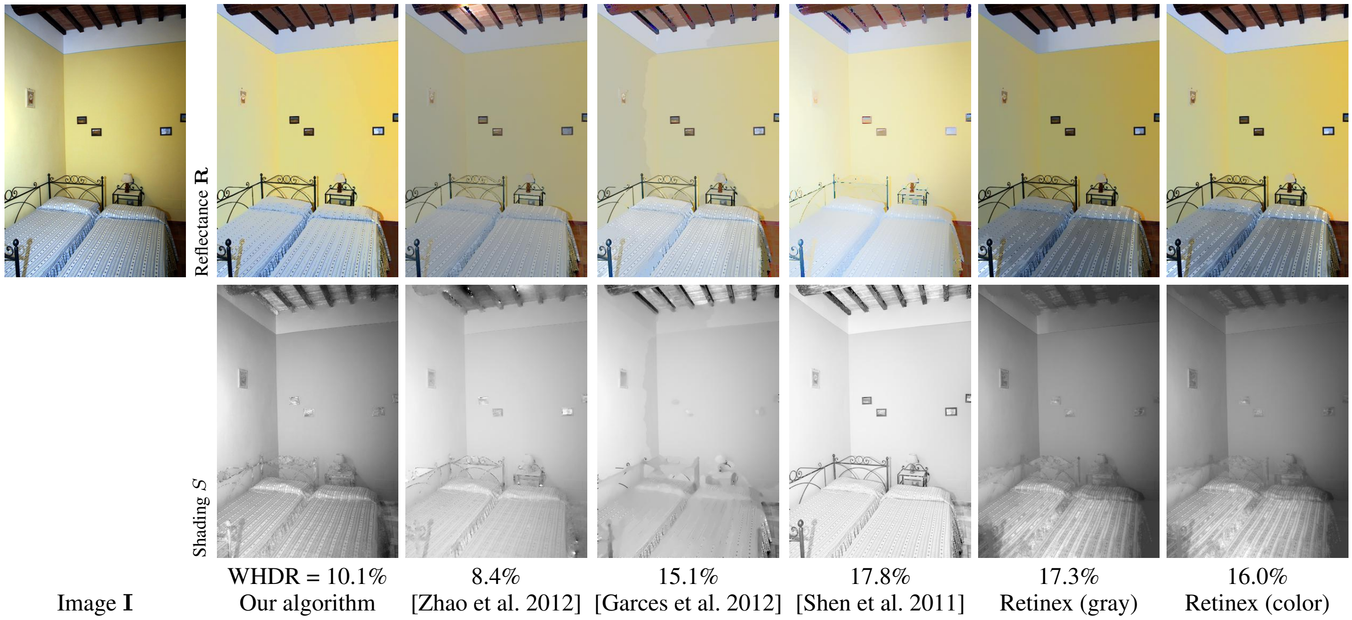


Figure 47: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 100313.*

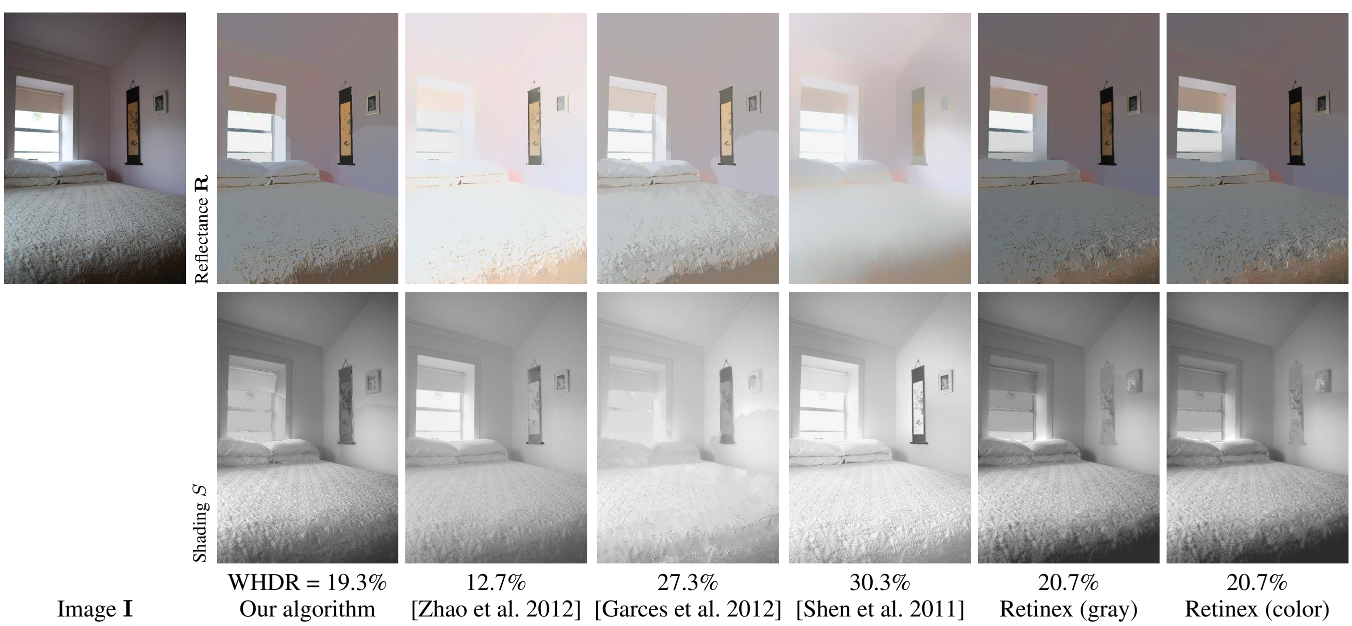


Figure 48: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 9843.*

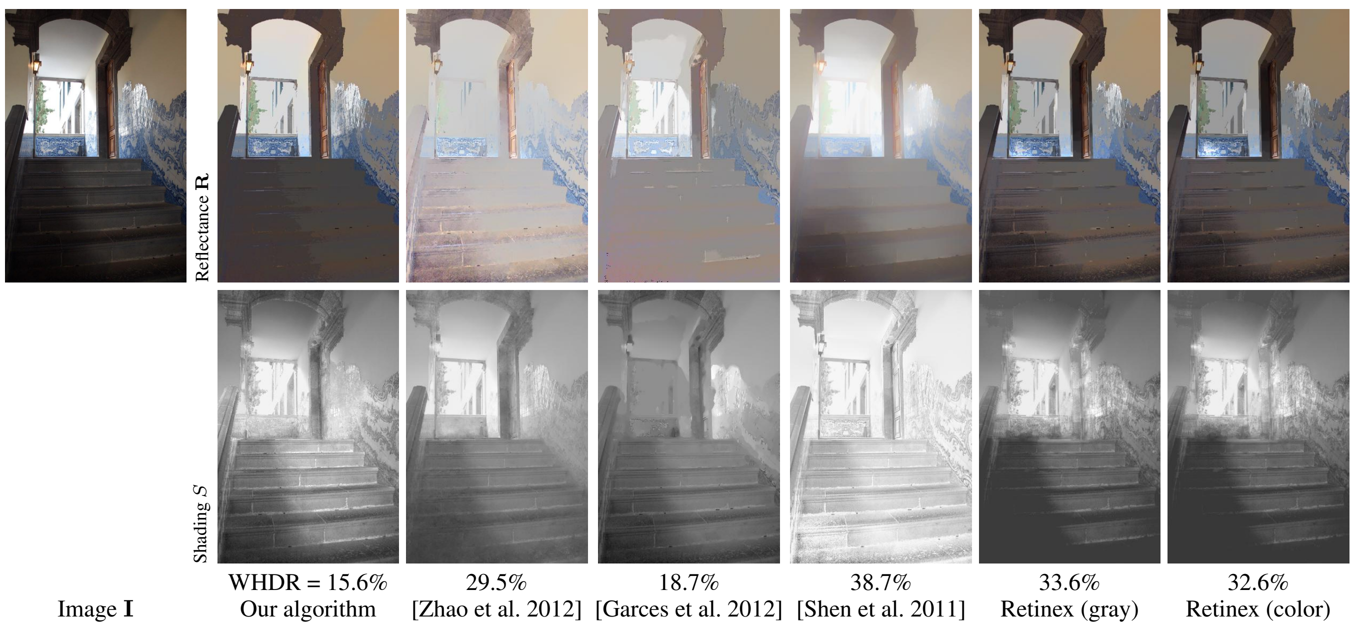


Figure 49: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 26776.*

Figure 50: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 57389.*

Figure 51: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 118510.*

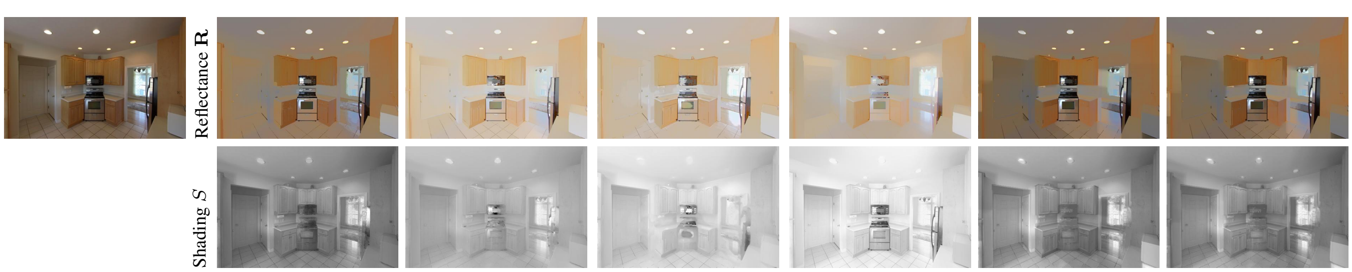


Figure 52: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 118509.*

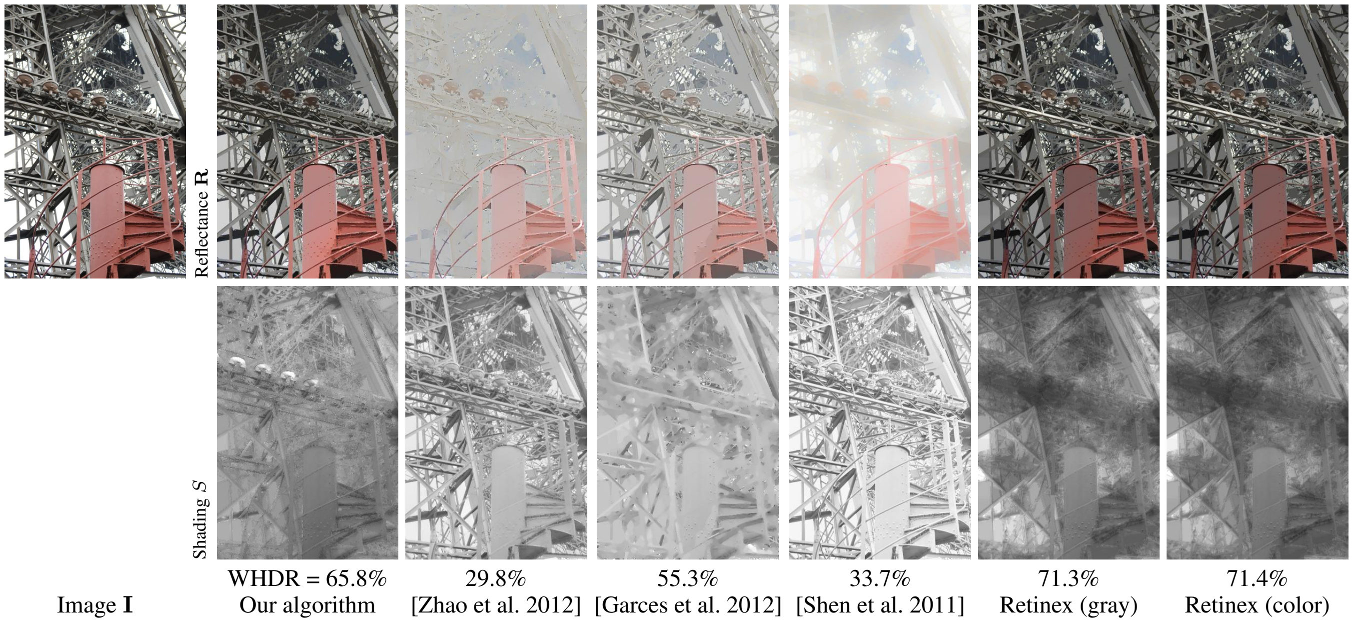


Figure 53: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 25172.*

Figure 54: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 60889.*

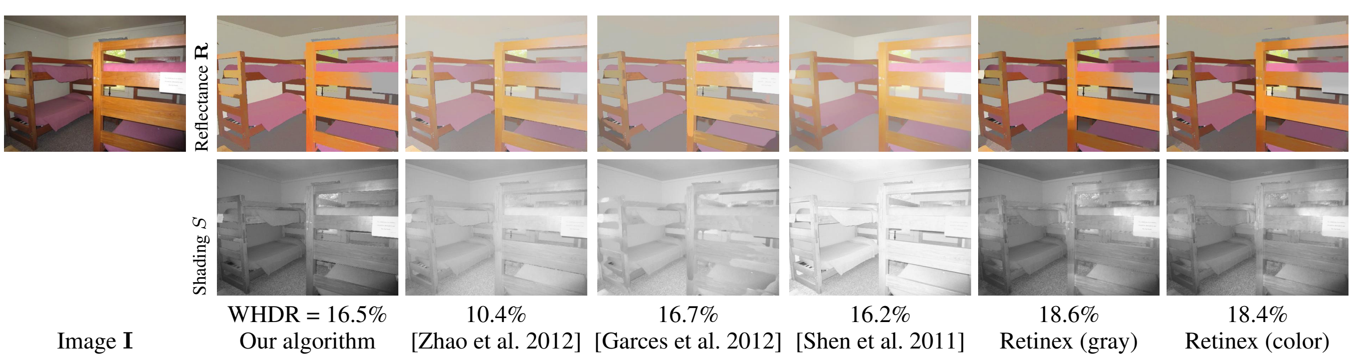


Figure 55: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 98498.*

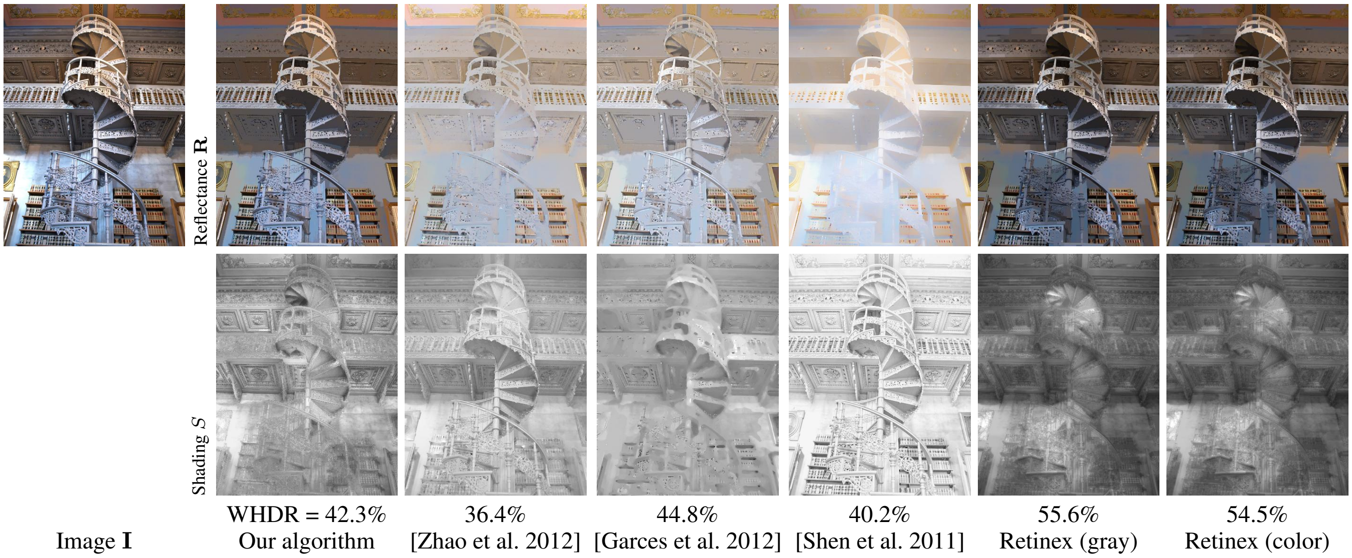


Figure 56: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 9438.*

Figure 57: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 107243.*

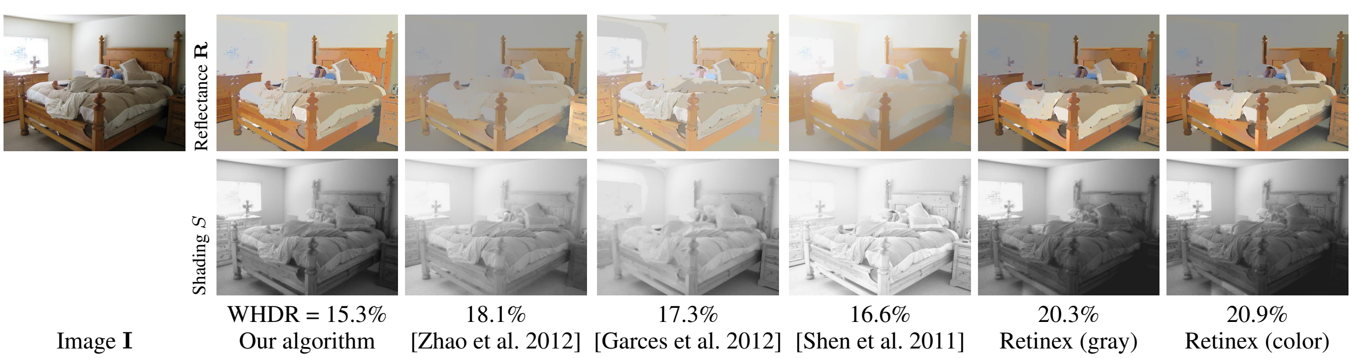


Figure 58: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 105788.*

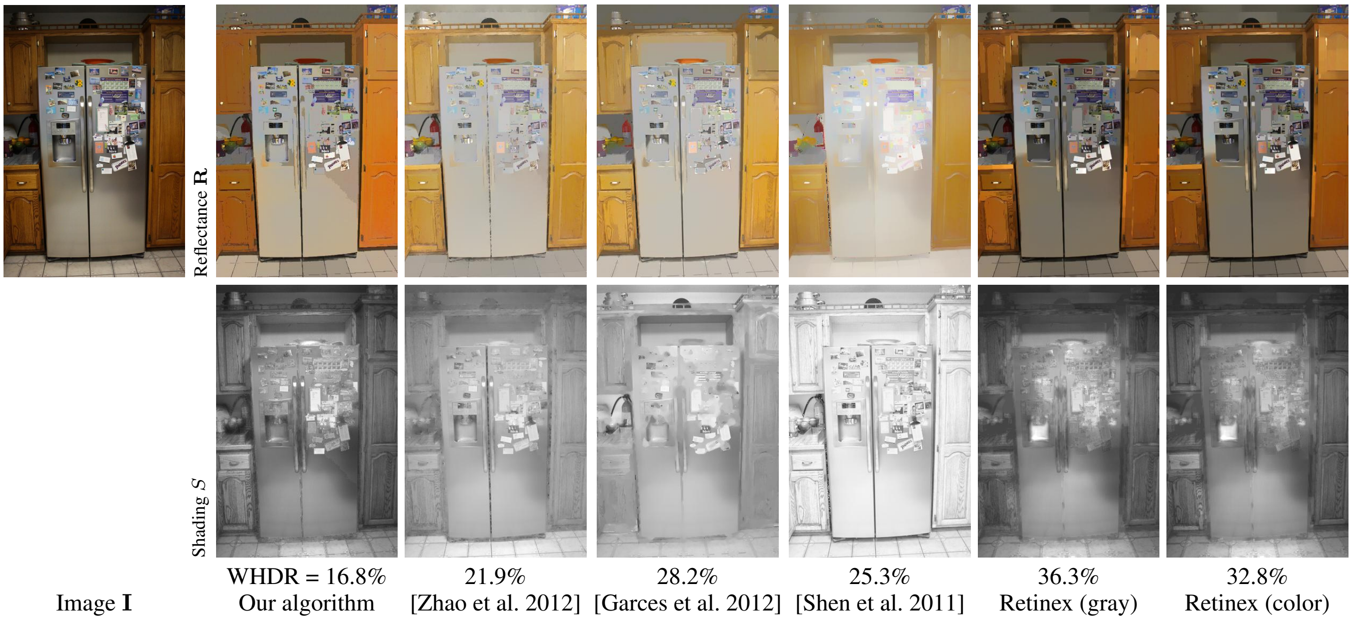


Figure 59: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 86846.*

Figure 60: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 89875.*

Figure 61: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 108975.*

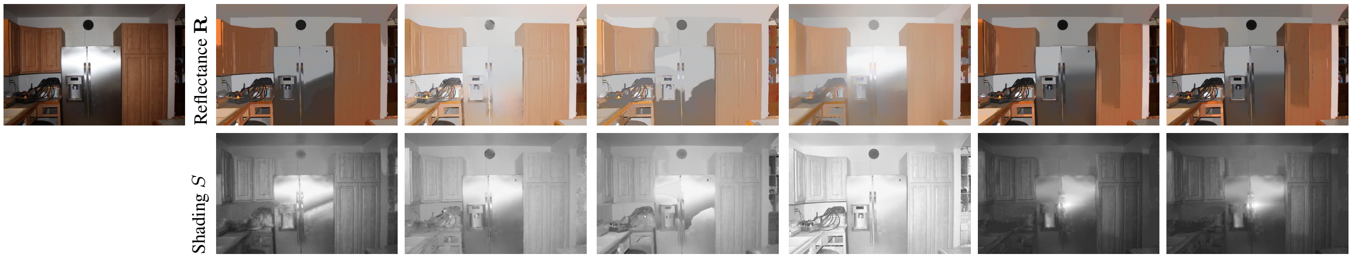


Image **I**	WHDR = 14.4% Our algorithm	15.4% [Zhao et al. 2012]	15.7% [Garces et al. 2012]	20.9% [Shen et al. 2011]	24.5% Retinex (gray)	26.3% Retinex (color)

Figure 62: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 3446.*

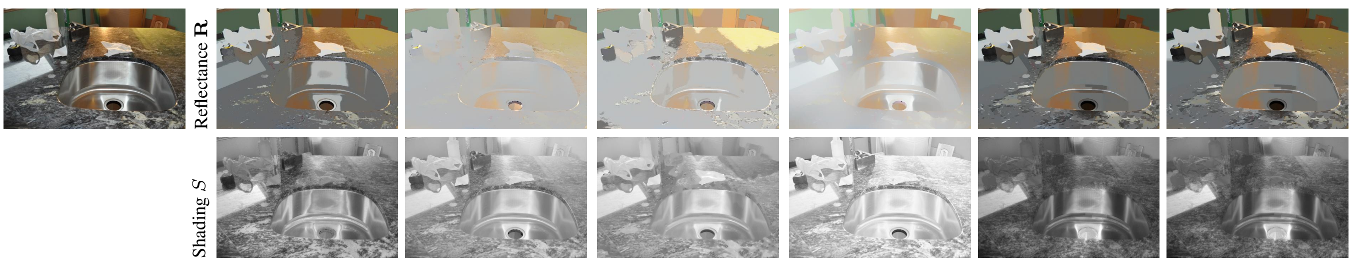


Image **I**	WHDR = 29.4% Our algorithm	16.8% [Zhao et al. 2012]	30.9% [Garces et al. 2012]	28.2% [Shen et al. 2011]	27.0% Retinex (gray)	26.2% Retinex (color)

Figure 63: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 83586.*

Image **I**	WHDR = 31.5% Our algorithm	28.9% [Zhao et al. 2012]	33.1% [Garces et al. 2012]	29.6% [Shen et al. 2011]	39.5% Retinex (gray)	38.7% Retinex (color)

Figure 64: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 103319.*

Image I	WHDR = 19.9% Our algorithm	31.4% [Zhao et al. 2012]	24.7% [Garces et al. 2012]	24.6% [Shen et al. 2011]	17.5% Retinex (gray)	16.6% Retinex (color)

Figure 65: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 82917.*

Image I	WHDR = 42.4% Our algorithm	53.0% [Zhao et al. 2012]	34.0% [Garces et al. 2012]	45.2% [Shen et al. 2011]	48.8% Retinex (gray)	49.4% Retinex (color)

Figure 66: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 101573.*

Image I	WHDR = 14.3% Our algorithm	32.3% [Zhao et al. 2012]	23.3% [Garces et al. 2012]	25.7% [Shen et al. 2011]	40.1% Retinex (gray)	40.0% Retinex (color)

Figure 67: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 57204.*

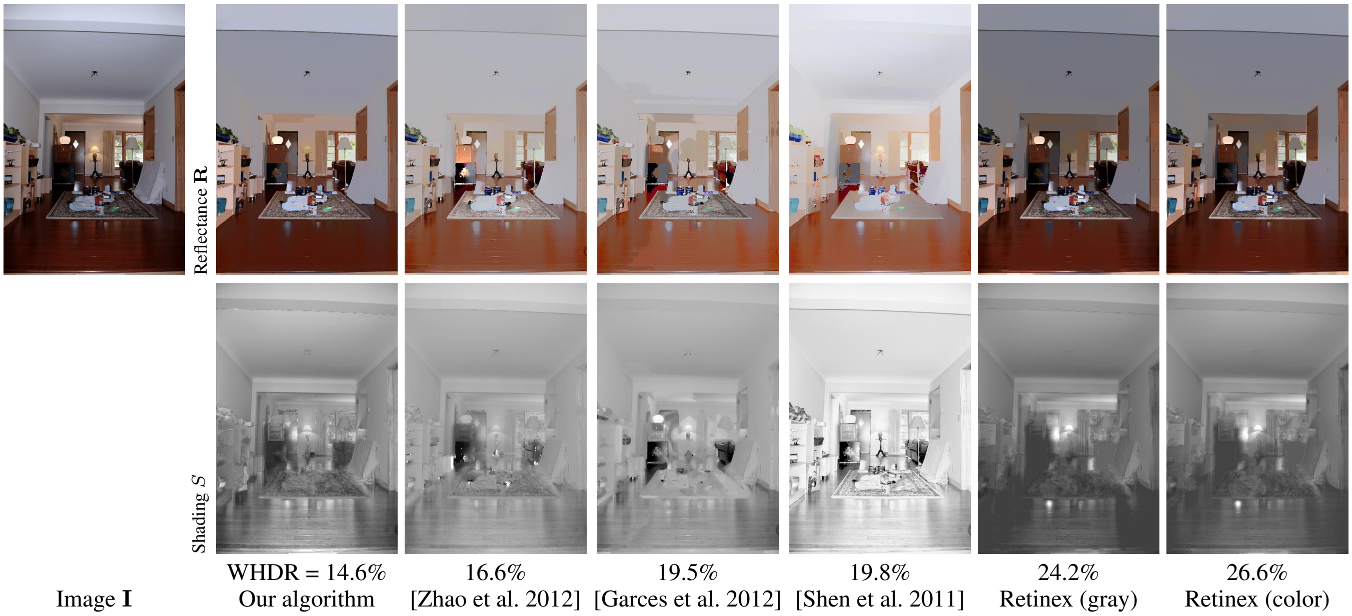


Figure 68: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 109759.*

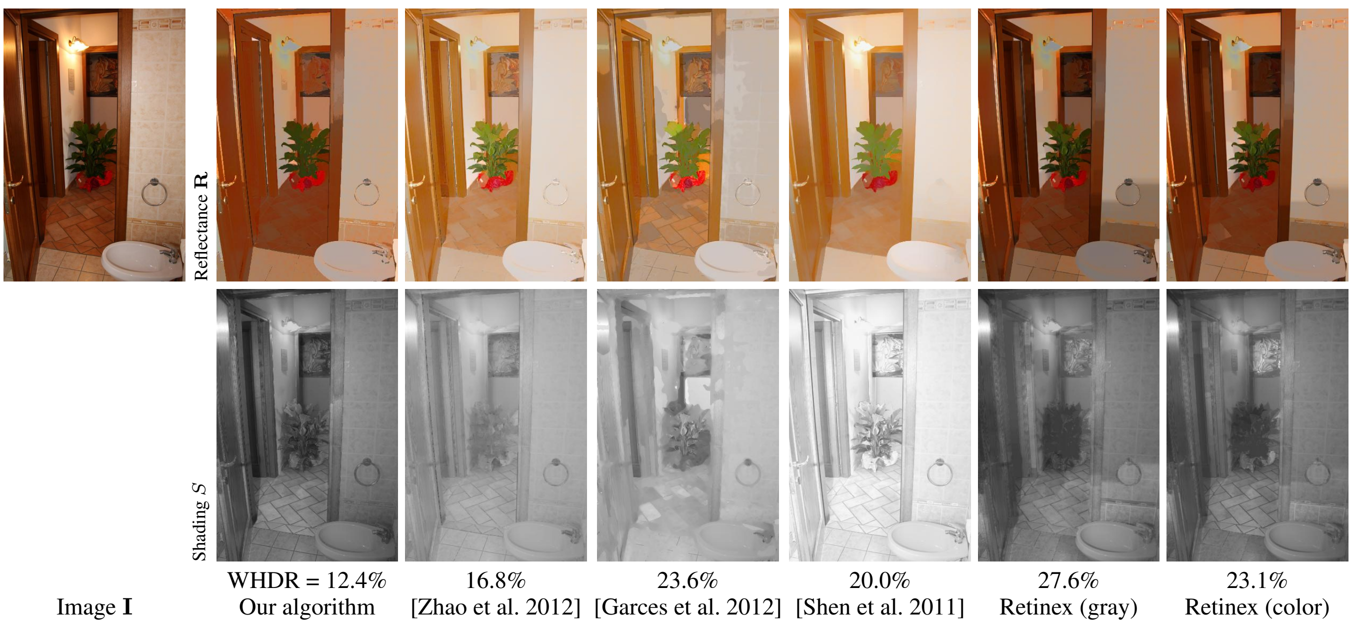


Figure 69: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 15554.*

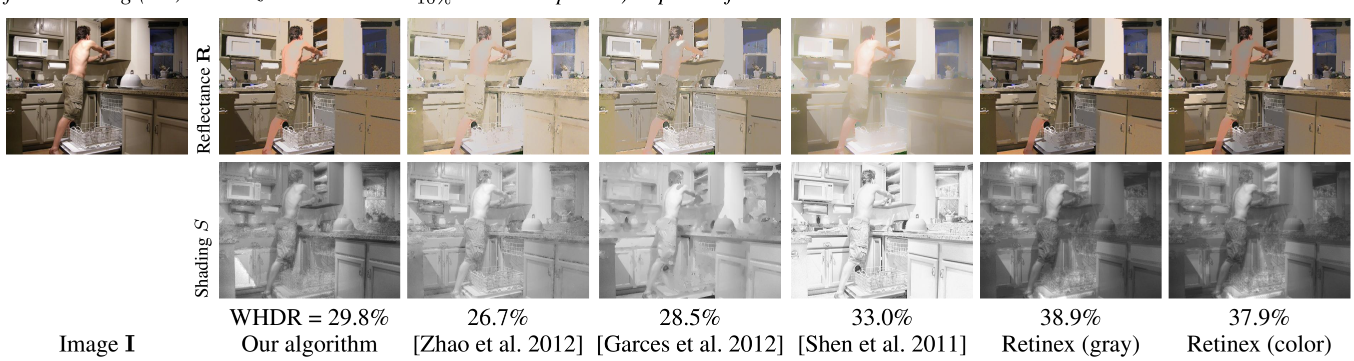


Figure 70: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 69278.*

Figure 71: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 83161.*

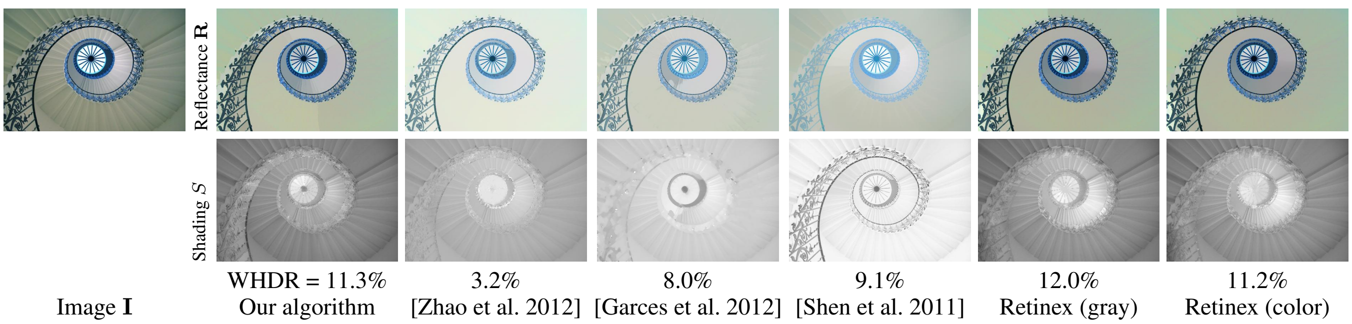


Figure 72: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 24947.*

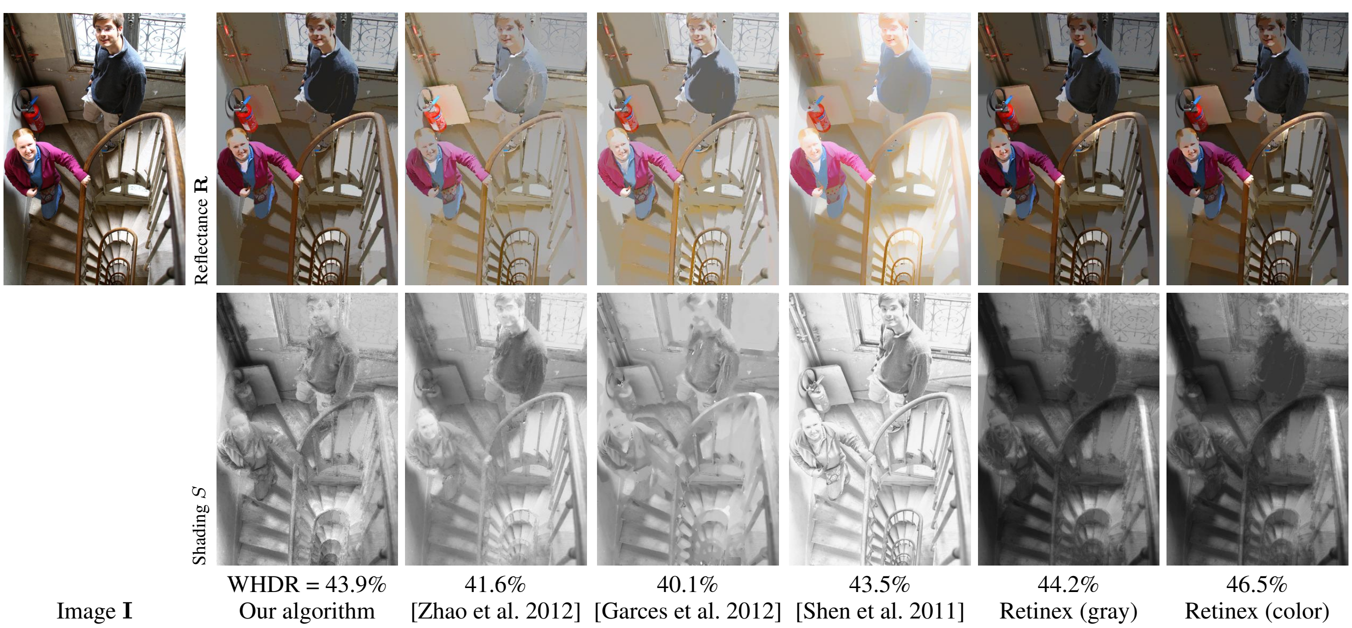


Figure 73: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 24564.*

Figure 74: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 62855.*

Figure 75: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 117613.*

Figure 76: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 26128.*

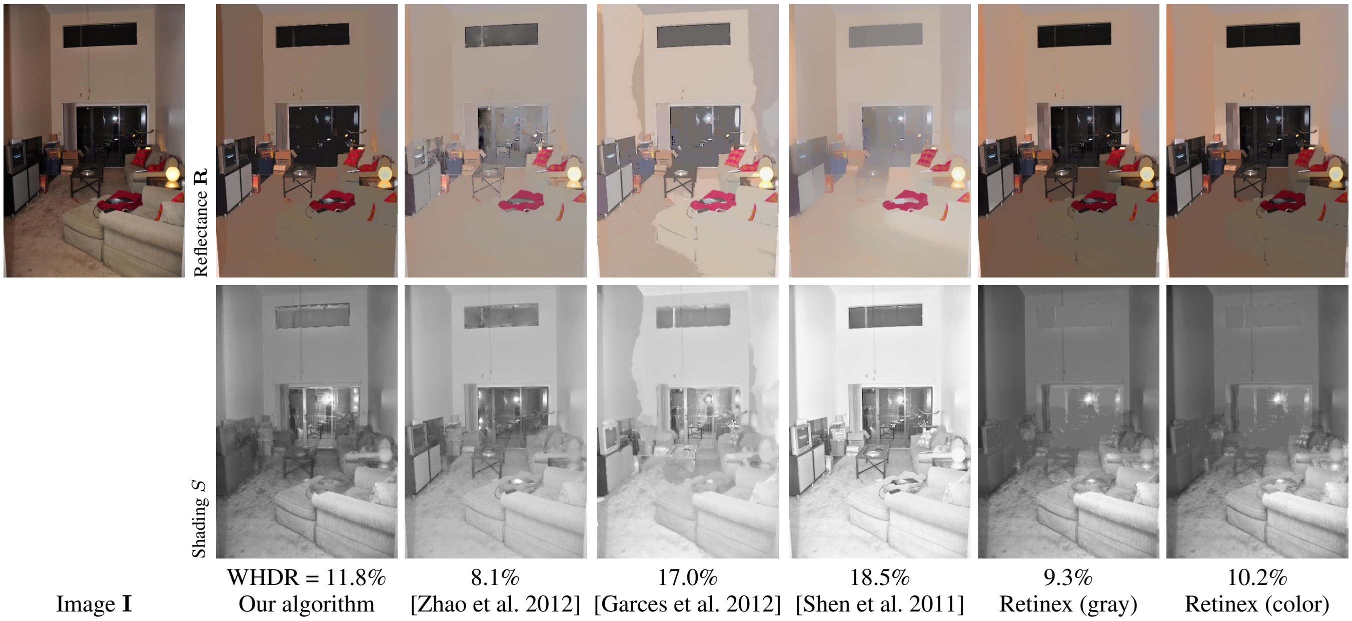


Figure 77: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 35918.*

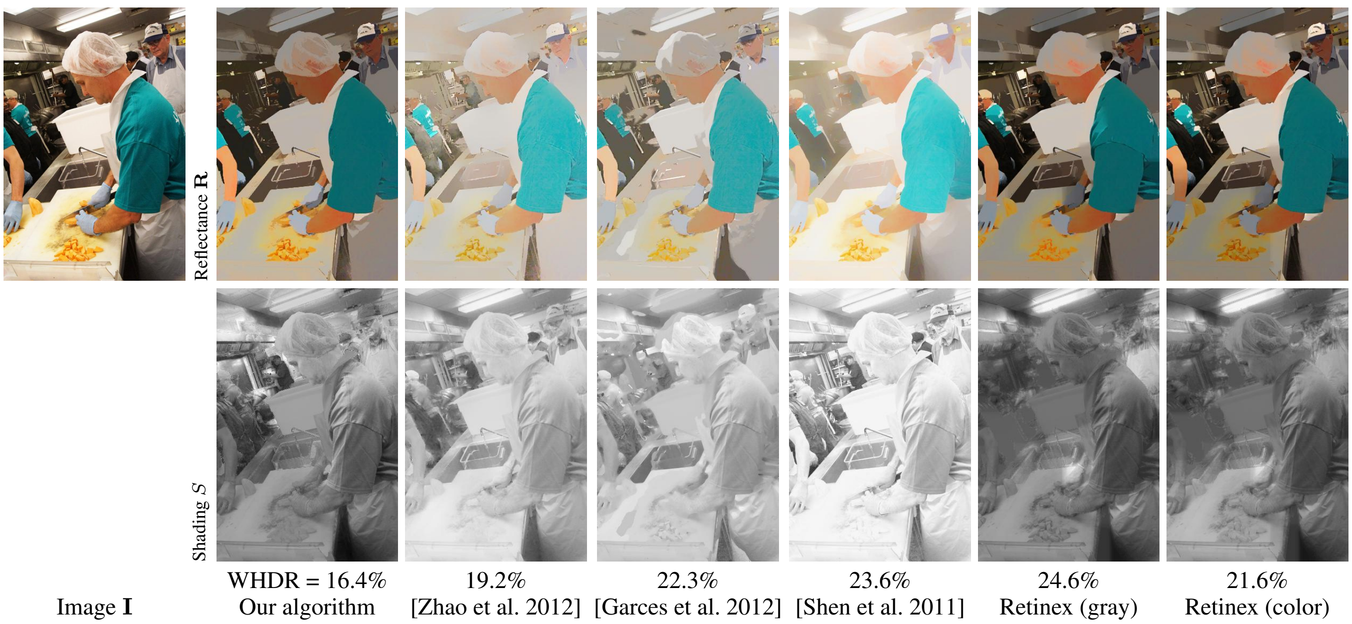


Figure 78: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 56665.*

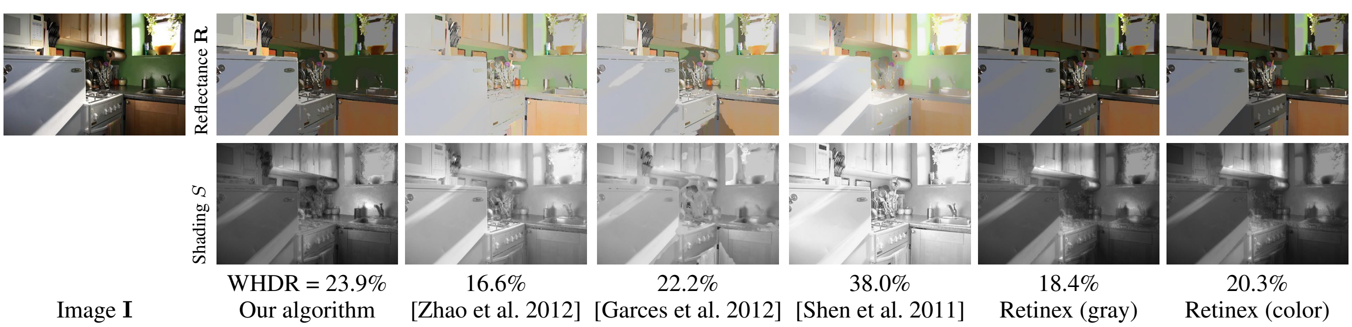


Figure 79: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean WHDR$_{10\%}$ across all photos). OpenSurfaces Photo ID: 83285.*

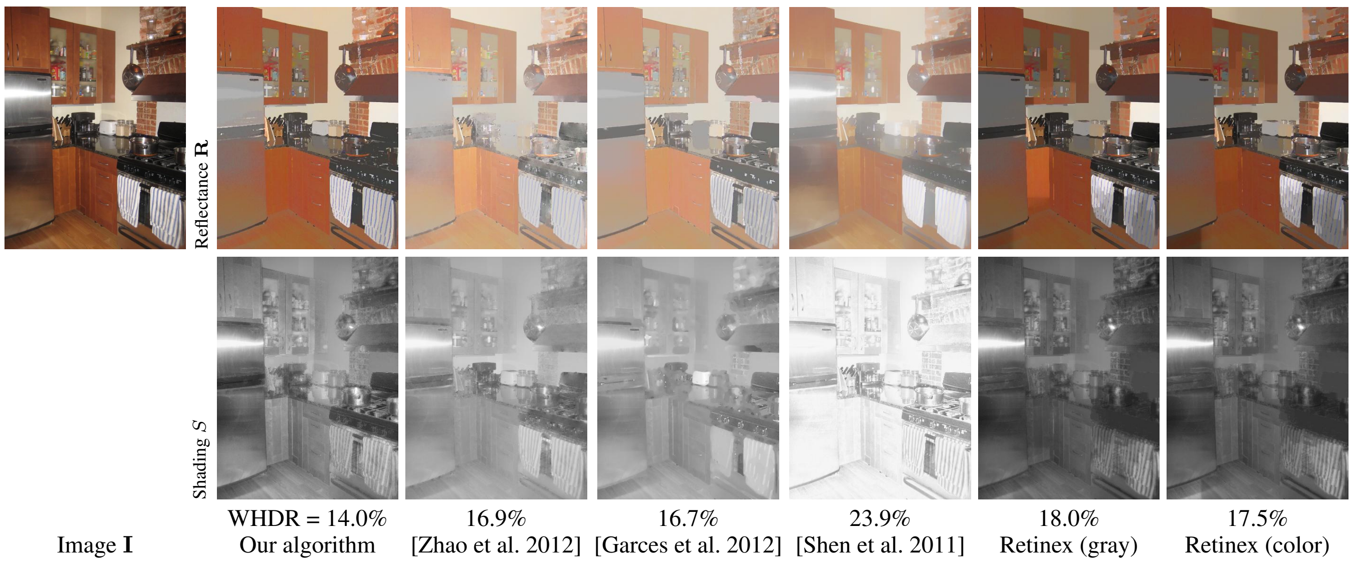


Figure 80: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 84040.*

Figure 81: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 35804.*

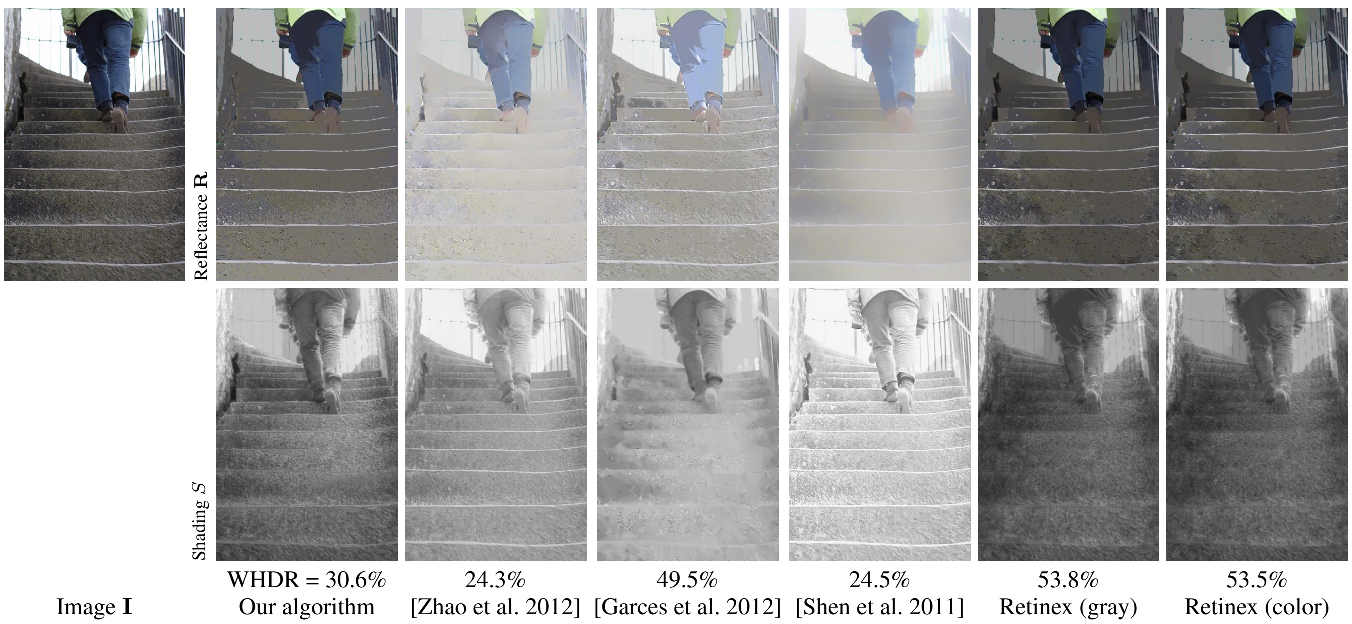


Figure 82: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 22645.*

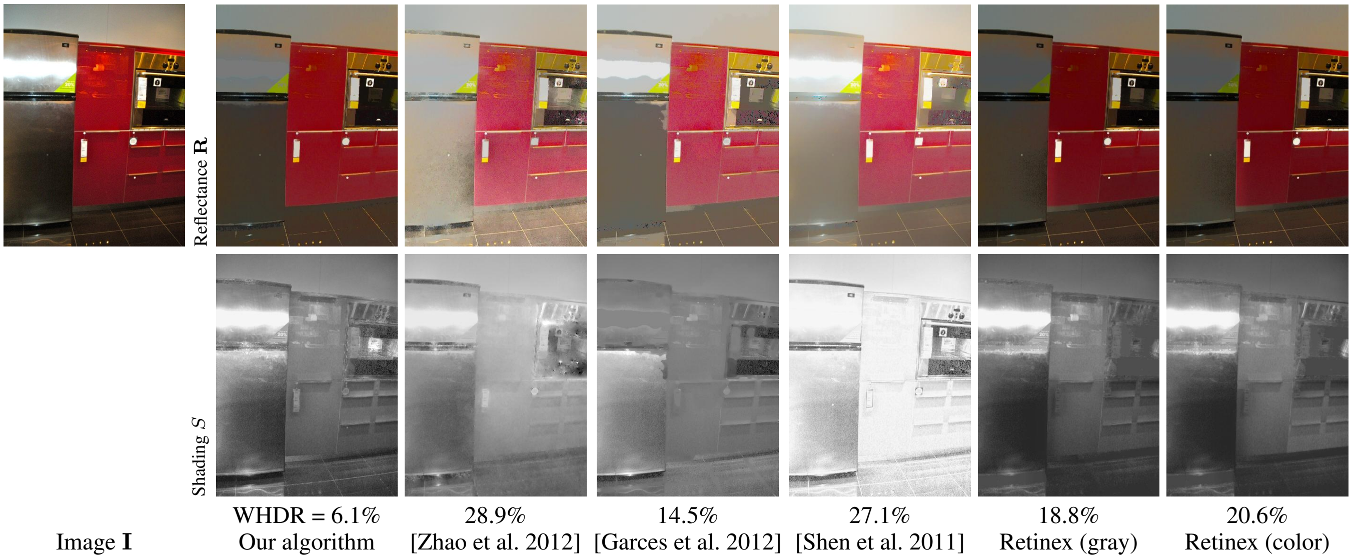


Figure 83: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 68084.*

Figure 84: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 116213.*

Figure 85: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 66411.*

Figure 86: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 69088.*

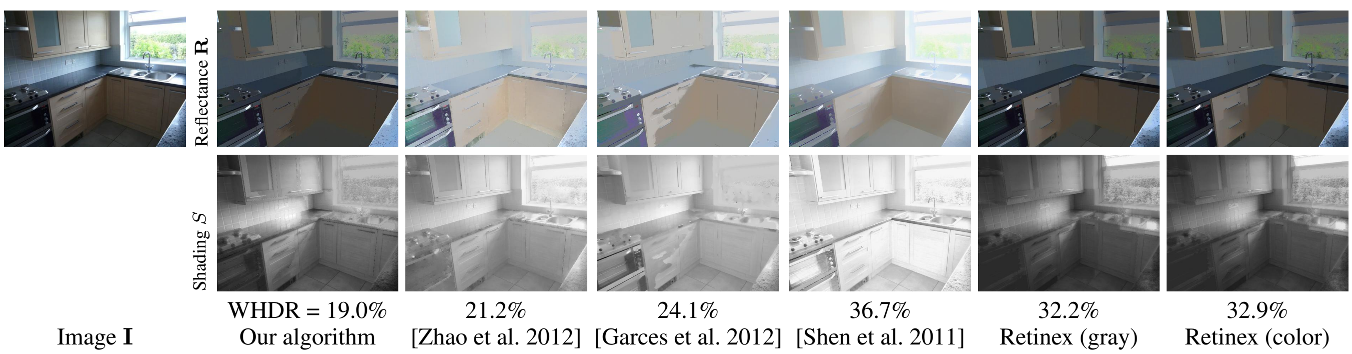


Figure 87: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 83252.*

Figure 88: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 59157.*

Figure 89: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 11877.*

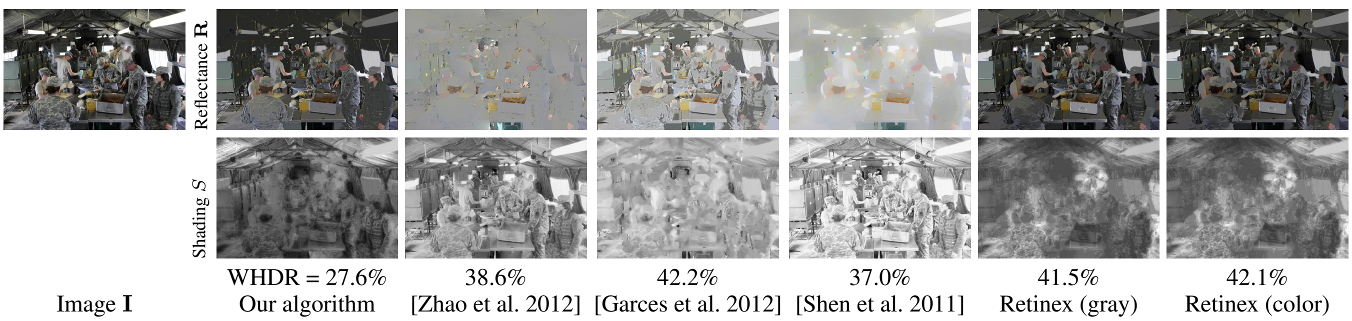


Figure 90: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 82342.*

Figure 91: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 11902.*

Figure 92: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 97331.*

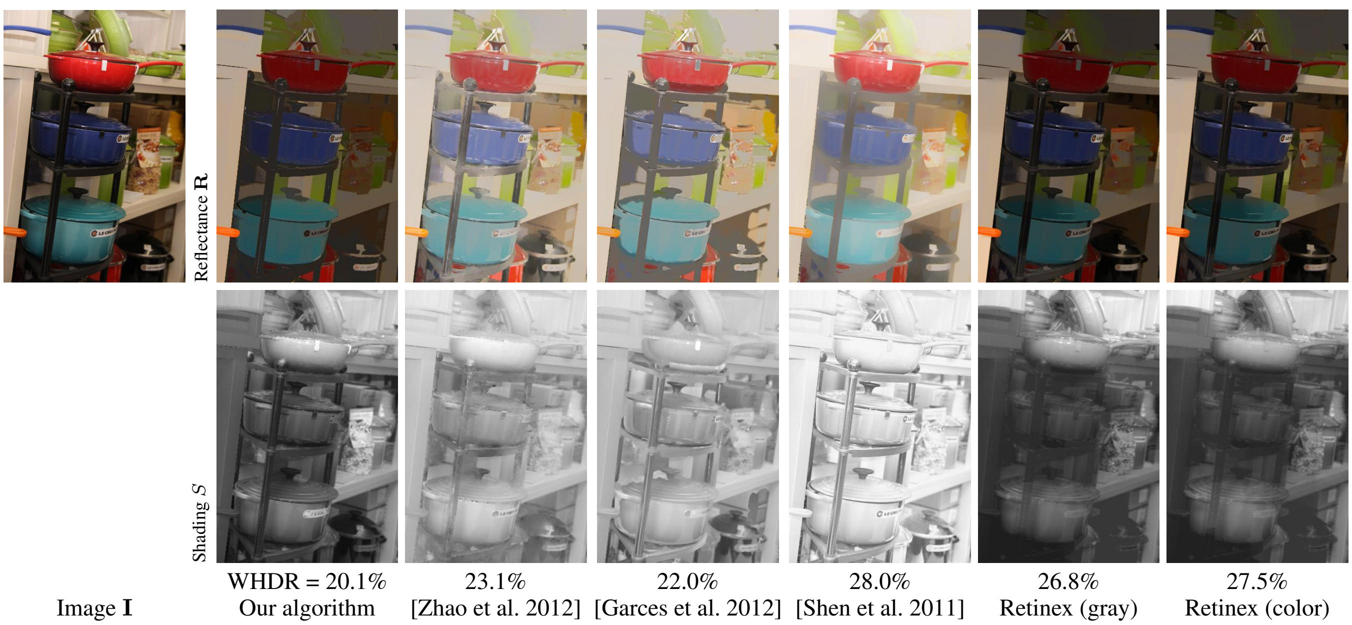


Figure 93: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 74588.*

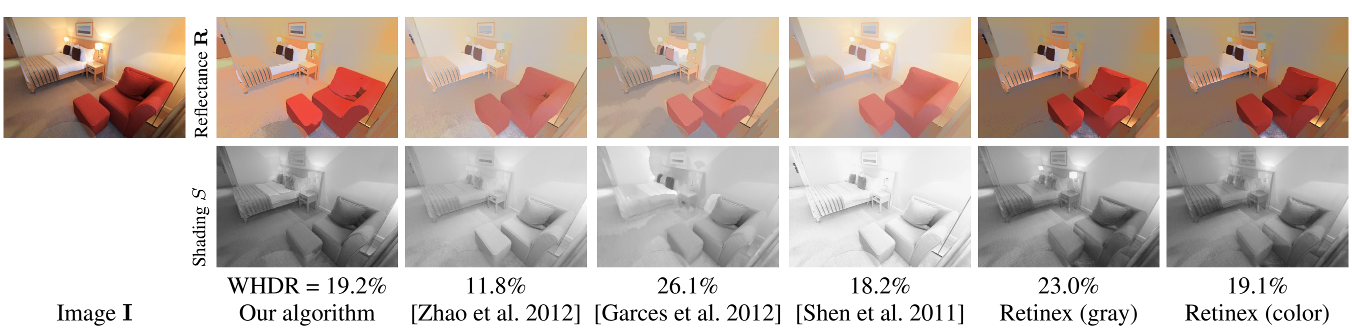


Figure 94: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 105618.*

Figure 95: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 97664.*

Figure 96: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 57372.*

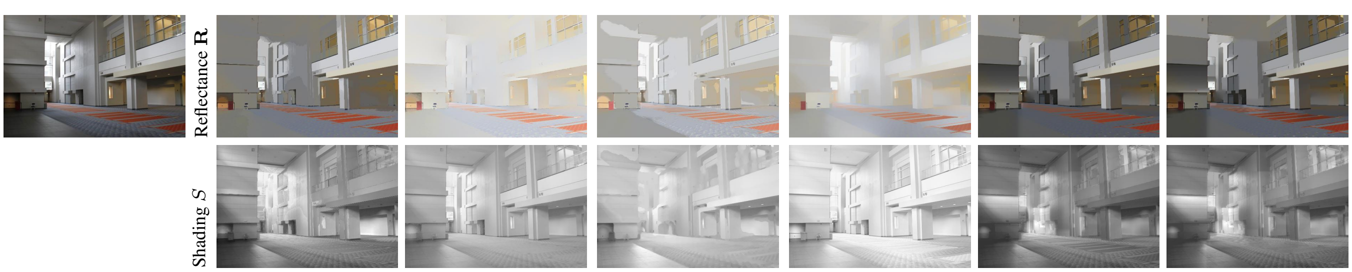


Figure 97: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 108117.*

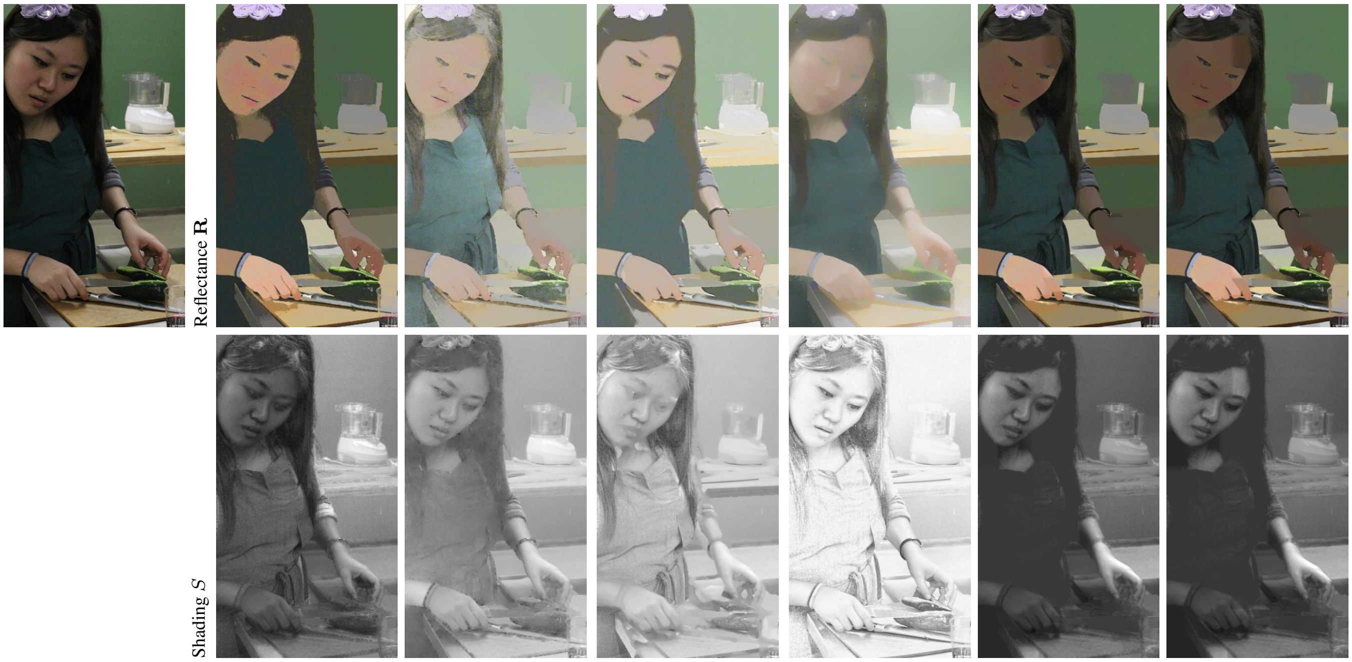


Figure 98: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 114659.*

Figure 99: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean $WHDR_{10\%}$ across all photos). OpenSurfaces Photo ID: 56068.*

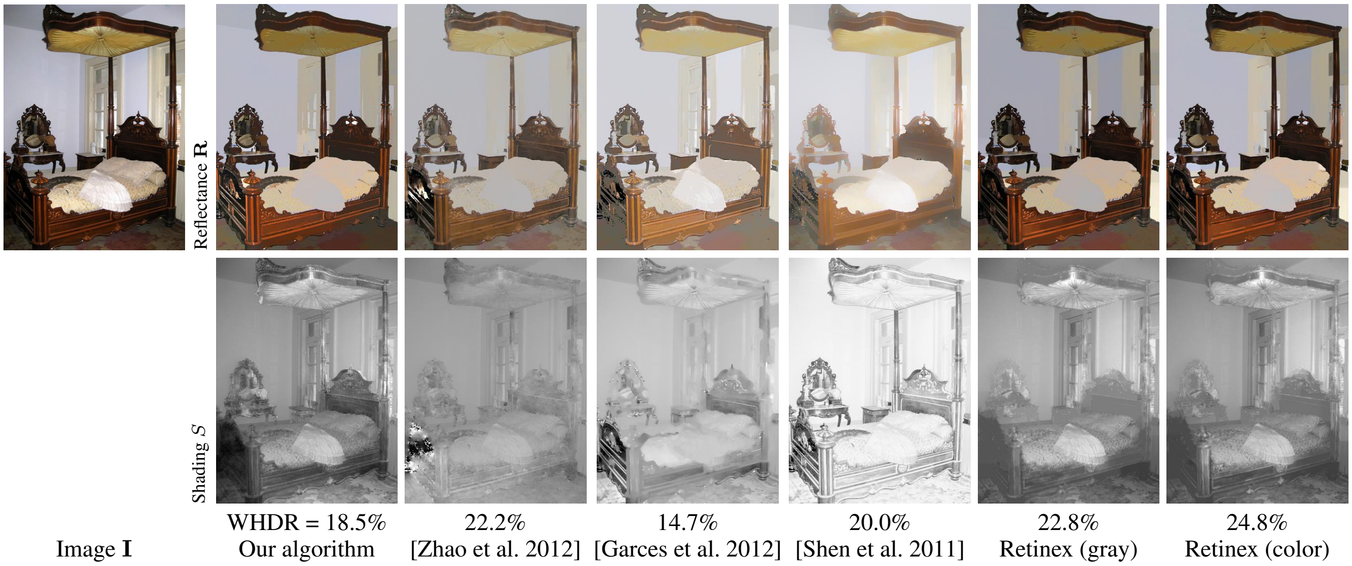


Figure 100: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 105479.*

Figure 101: *Visual comparison of our algorithm against several recent open-source algorithms. Each algorithm uses the best parameters found from training (i.e., minimizes mean* $WHDR_{10\%}$ *across all photos). OpenSurfaces Photo ID: 112291.*

4 Additional acknowledgments: Flickr users

Finally, we would like to thank the following Flickr users (by User ID) for releasing their images under a creative commons license. This work would not be possible without their contributions:

-jvl- 1-25_sbct 11638547@N00 11777792@N06 11921146@N03 12394349@N06 13128823@N06 15132846@N00 15481483@N06 15985502@N00 16330500@N06 16725630@N00 17489999@N08 18472724@N00 19937318@N00 11n2ps 21154048@N04 21524179@N08 22179048@N05 22201094@N08 22711505@N05 22746515@N02 22748341@N00 22882167@N07 24454962@N00 25165196@N08 25395270@N02 25968780@N03 26085795@N02 26126239@N02 26346121@N06 26786061@N00 27164521@N00 28208534@N07 28384691@N05 28656738@N02 28685147@N04 28709589@N02 29222579@N05 29233640@N07 29278394@N00 29500824@N06 29651151@N05 30562163@N04 3059349393 30624565@N08 30742666@N06 31403074@N00 31403417@N00 32552299@N04 34128007@N04 35168673@N03 36397453@N00 36431049@N02 37457628@N00 38876728@N00 39718079@N00 401stafsb 41234246@N06 413studios 42402904@N00 42954113@N00 42dreams 43503694@N00 44563197@N00 45005153@N07 47512719@N00 49873808@N00 4u2lookat 50078007@N00 51653562@N00 52355157@N00 55231619@N00 57286185@N04 5wa 60186309@N08 60464669@N06 62313790@N00 62766743@N07 62904109@N00 65709822@N00 66252478@N02 68945279@N00 69166407@N06 69302634@N02 70118259@N00 70268842@N00 7161728@N04 71966930@N00 72213316@N00 73416633@N00 73542590@N00 73577218@N00 7458191@N03 75842363@N00 7666989@N04 77799978@N00 78428166@N00 807thpao 8136496@N05 85056813@N00 87341289@N04 88158121@N00 88979981@N00 89119745@N00 90664717@N00 90859240@N00 92795775@N00 93574830@N00 9364326@N04 9680862@N05 99943078@N00 _cck_ _vann a2community abbybatchelder absolutsara abundantc adamcaudill adamfletcher adselwood aeu04117 agizienski aharden aidanmorgan aiwells ajburstein akasped alamosbasement alan-light albertoalerigi alex_kuehni alexbrn allesok aloha75 alper amagill amanderson amayzun ameadows ammichaels amslerpix amy_elizabeth_west amyrod1 amysjoy anaru andie712b andrea_nguyen andreagp andrec andrewbain andrewkarigan andrewmalone andrijbulba andymangold aneebaba angeloangelo angusf anijdam anne-cathrine_nyberg annerossley anngav anodoin anselmhook antmoose aperte apeyton apreche aprilsanders aprily arandall arascats ardyiii armyengineersnorfolk arndog articulate artrca1000 arunmarsh aschaf ashkyd ashleytheartist2002 askthepixel asy atbartlett atgeist athomeinscottsdale atoxinsocks aturkus austinevan auxesis averain awnisalan ayoltderoos baileysjunk bakoko bakou67 baltimorejeff banna123456 barbcrawford bargas barndweller barockschloss baroquem barrypeters basheertome basykes baylors bbmexplorer beansandgrapes beckmann beggs beigephotos bellissima_italia ben_on_the_move bengarney benhusmann bennybenso bensutherland bert_m_b betsssssy betterthaneveryone bfauld1 bfishadow bhaven bihammond billward billyoneal binaryape birdbrian bjuli bjvs blmurch blucier bludgeoner86 bluefootedbooby blumenbiene bmbcphotos bobaliciouslondon bobolink boboroshi bogen bonitalabanane bonniebogle booleansplit bootbearwdc bowbrick bptakoma bradcerenzia bradfordcoy bradleypjohnson brandnewbrain brandonthemandon brazilnut72 brentdpayne brentnewhall brian395 brianandjaclyn briangratwicke briannaorg 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cote cplbasilisk craftivist-collective cristiano_betta croco crown_molding cs-jay ctsnow cubanrefugee cybergypsy cybot586 cygnus921 cypher386 d_wilkinson08 dachis dahlstroms damork dan4th dana_moos danielavladimirova danilopaissan dankate danramarch daquellamanera darinhercules davef3138 daveiam daveyphotos davidcjones davidnoah davidspinks dawgs1265 dbdbrobot dbgg1979 dccentralkitchen dcoetzee ddaarryynn deansouglass deborahmain deidrew deity dennajones dennis denniswong der_robert derekskey designandtechnologydepartment designsbykari dfid dgmckelvey dharrels dickdotcom dickpenn dicksonyue digidreamgrafix digital_ramapge digitalsextant dinnerseries discoverdupage disneyworldsecets dist0rtedwave dittaeva djmax dmertl dnamichaud docmonstereyes doglotion dogpaste donabelandewen donhomer donna-andrew doortoriver dottieg2007 dpape dprevite dpstyles drcw drivingthenortheast droff09 dsifry dsix dumbledad dv_flick dvanhorn dwilliss dylancantwell e-licious eblake ecristescu edastrauch edbierman edenpictures editor edkohler eelkedekker egfocus eggrole egoant eguidetravel ekigyuu eklem elaws elias_daniel eliazar ell-r-brown ellenm1 elmiracollege elvissa elwillo elzey emeryjl emilysnuffer emmajane empracht emrank emseetwo endbradley endymion120 envizion epaul_07 ephidryn eplus-gruppe epsos eri-design ericyeargan erikkristensen erocsid estrelas eswift euan-donna europedistrict evanblaser everydaypants ex_magician exfordy eyeliam fatedenied felipeskroski ffg fifikins film_fatale fimbrethil fincher69 firepile fishermansdaughter fitri-agung flexsleuthor flissphil flottenheimer footfun footloosiety forbzez fortvancouvernps fotnmc foxtongue fran001 frogbelly ftleetraveller ftzdomino functoruser fungleo fusion_of_horizons fussyonion futureshape futurestreet fuzzy gamene garlandcannon garysoup gastev gavinmusic gavinr gazeronly gcwest gee01 gemsling gesika22 ginevra gingerbydesign giustino globaltrotters gnuckx goaskaliceithinkshewillknow goincase goldberg goodhugh goodncrazy goodrob13 gooseotter goosmurf goproject gordontarpley gottgraphicsdesign gottshar governordayton graeme grahamandsheila grahambones grammarshy greencolander greggjerdingen greggman gregthebusker gregwalters grenade greyworld gro gromgull grongar gruene-bundestag gruenemann gsloan gtzecosan gusilu hagengraf hal990 hankhession hankzby hansnyc happenstancephotos happy_mermaid happyskrappy hari_singh harlequeen harshlight hdreisler heatheronhertravels hectoralejandro helloturkeytoe hendry henofthewoods herry heschong hiddenloop hisgett hitchster

hockeyholic hodac hollandnm hombredesteele hooverine howieluvzus httpwwwflickrcomphotostopend hugo90 humblog hurricanemaine hutchike hygienematters iamagenious ian_d ian_munroe icanchangethisright ifl igb igboo ijammin iluvcocacola indi infinitelydigital ingamun inkiboo innuendo interval ipeguy irishfireside istolethetv iurikothe iwona_kellie j_benson jackhebert jackiembarr jakecaptive jamiesrabbits jammydonutworld japharl jared422 jareed jasonpratt jaybergesen jaycross jbcurio jbristowe jcbrandon jcfrog jcmedina jeffchristiansen jeffedoe jeffk jeffsand jeffwilcox jemimus jenniferboyer jennycu jenorton jenrobinson jeremylevinedesign jerine jesse jesse757 jgodsey jgoforth jiannone jigodance jillallyn jimg944 jkirkhart35 jm-photography jm_photos jmansskittles jmrodri jnewland jnissa jns001 jo-h joccay jodimichelle joebeone joelovesneian joelwashing joeshlabotnik john_lustig johnloo johnnydante josephers jronaldlee jrover jrproductions2012 jshontz juanmaiz juggernautco juhansonin juliejordanscott jurvetson justinfaulkner jvh33 jwajennalex jwthompson2 jwynia jyri k4chii kaichanvong karenandbrademerson karenhorton karlfrankowski karrienodalo katerha kelp ken_mayer kendoerr kendylyoung kenspix kevandotorg kevingessner kevinkrejci kevinmgong kevint3141 khargrav kiditamae killahpoopface kirbyurner kirrilyrobert kiry kitchenbp kitpfish kjarrett kjc9 kjfnjy kkendall komunews korimatiessa kowaleski kristieg kroszka ktylerconk kwl kylepeyton l2f1 lakemartinvoice larry1732 larsjuh laundry laurelville_gallery lauren_michell laurgasms lavenderstreak ledocce leemcarthur lehighvalleypa lejoe lentini lesphotosdejerome librarianavengers librarianidol lidocaineus liferfe lilu12323 lindatrawnik lindsaydeebunny lindyy linpadgham lisgirl lizadaly llstalteri lmdo lodicks loimere lollaping london londonmatt lonetown lordphantom louandtraciplus louisecohen louisvilleusace loweroaklawn loyaldefender2004 ltobrooklyn lukegordon lwy lydialark lyng883 machineisorganic macsurak madeleine_h maelvillafranco maganyoung magickevin magneticmediafed magnus_d mahinui makefruitfair makelessnoise maladjusted malcolmtredinnick mamchenkov manousek marciatoddrealtor mariachily markdoliner marko8904 marshey martin_thomas marymerry marysalome masonulife mathplourde mattandkim mattfour mattimattila mattkern mattritchie maureendidde mauriceking maveric2003 mccun934 meddygarnet meesterdickey meganschuirmann melanie-m merajchhaya merfam mhowry michaeljohnbutton michaelsgalpert michalo miggslives mikebaird mikehamm mikelewis mikewarren millsbaker minka6 missbossy misschatter missyward mister-e misteraitch mitchell3417 mjanicki mlevisay mommy2seamus moonlightbulb moresheth morgandavis moria movitz mrperry mshades msisk msk mskogly mugland mujitra munir mustbeart mwf2005 mwichary myboogers myfavoritepetsitter mymollypop mystikrvn naan nagarjun nanpalmero nasa_goddard nataliemaynor nate nathanmac87 natjwest nattarbox nayoungkim ndrwfgg nealea near_fantastica nebulux neeta_lind neilrickards newton nicholassmale nickwade nickwebb nicokaiser nieve44 nikijulian nikisublime nile_red nirak nostri-imago nyc_xmas oabe observatoryleak oceanyamaha odolphie offutt_afb oggiedog ohmeaghan okchomeseller oldrebel oliverlyon omaromar on1stsite onefromrome opie orangelimey orcmid orinrobertjohn orphanjones orphum osseous otosphotos p_x_g pagedooley pagel pamlovespie panamapictures papa-t pardee parisharing pasa pasfam pat_ossa patio paul_a_hernandez paul_lowry paul_white pavdw pawlowski pedronet perspective petercastleton peterhess peterlong petruniak pftqg phalinn phelyan philliecasablanca photofarmer picken pinguino pinkmoose pinksherbet pixelchecker pjgardner plindberg plong plutor poisonbabyfood pong popiet porchswing porsche-linn portobaytrade powerbooktrance precision primejunta probabilistic proimos proxyindian psd pugno_muliebriter punktoad puroticorico puuikibeach qmnonic quiltsalad quinet quirky qwrrty rachelmargaret raeallen randalldegges randysonofrobert rasmusknutsson rayb777 raybouk razvanorendovici rberteig rbitting rbowen rdmey rdrpr rduta realcsi realestatezebra reizzil respres restlessglobetrotter rexroof rhadad rhinman richardmoross riebart riggenransom rimesparse rjshade rkramer62 rlerdorf rob-young robandstephanielevy robcook robertluna3 robertpaulyoung rocketboom rocketjim54 roguelazer roland roughgroove royluck rrunaway rsutphin rtadlock rubbermaid russelljsmith rutlo ryanboren ryanfrost ryanready saboten_ sackerman519 salanki salvadonica santafeegret saragoldsmith sarchi savannahcorps scissorfighter scott1723 scottfeldstein seat850 sebrenner seedkeeper seier seligmanwaite sellis selmer sergemelki sethwoodworth sgt_spanky shalbs shaneglobal shankbone shawnhargreaves shazbot sheepbackcabin sheila_sund shilad shimercollege shirokazan shokai shortfatkid shreveportbossier shutterbc siberianluck sidelong sidewalk_flying sightrays simoncook simondee simononly sirmildredpierce sixteenmilesofstring skellysf sketch22 slgc slightlyeverything slightlywinded smomashup1 snaks snapdragonmedia snowangel_1967 snre so__p sodexousa soltenviva sonofgroucho southernfoodwaysalliance sparragus spd-sh speculummundi spencersbrookfarm spidere spigoo spilt-milk srgblog srslyguys staceyhuggins starrett sterlingcollege stevensnodgrass stevier stewart stp striatic stublag studiobeerhorst suavehouse113 sue_elias suecan sundaykofax sunny_johns superdeluxe superfantastic supermac suzanneandsimon swimphoto syverson tachyondecay tammra tanais taylorandayumi tazza tdd tedandjen terryballard terwilliger911 tfduesing thbernhardt theaterderkuenste theco-operative thedanafiles thedelicious thedza thefadedpast theogeo therealhershey theresasthompson therichbrooks thescottclan thetalesend thomaspix thomasrstegelmann tim_uk timgillons timmccune tinali778 tinkerszone tinyfroglet tirch toolmantim topgold topsteph53 tpavel tranztec travelingotter trec_lit trevorandmarjee trishhhh tristanf trix_smith trydberg tsakshaug tulanesally twak twohungrydudes tylerkaraszewski uberculture uberzombie ubrayj02 ucdaviscoe ufv uggboy uitdragerij ukanda uncorrectedproofs upsand usagapg usaghumphreys usarak usarmyafrica usdagov usnavy vagueonthehow valerioveo variationblogr vasenka vastateparksstaff vax-o-matic veganfeast veisto veni vialbost virtualcourtney visitfingerlakes viucsr vix_b vmiramontes vox_efx vxla w00kie wakxy wallslide wandrus wasav wastes webdiva weinelt wengs wfyurasko wheany wien-vienna wisley wkharmon wlcutler wm_archiv wneuheisel wolfe-mckeel wolfsavard wonderferret wonderlane wordridden wwarby wwworks xshamethestrongx yakobusan yama2k yarhargoat yellowbookltd yeowatzup yimmy149 yinghai83 yourbartender zamkov zappowbang zeimke zombieite zric zzascape

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