A Realistic Surface-based Cloth Rendering Model (Supplementary Document)

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CCS CONCEPTS

• **Computing methodologies → Rendering**.

KEYWORDS

cloth rendering, microflake

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1 REFLECTANCE AND TRANSMITTANCE OF OUR BSDF

Surface Reflection. The specular reflection term $f^{r,s}$ is defined following the SpongeCake model, as

$$f^{r,s}(x, \mathbf{i}, \mathbf{o}) = \frac{k^{r,s}(x) D(\mathbf{h}, x) G^r(\mathbf{i}, \mathbf{o}, x)}{4(\mathbf{i}, \mathbf{n_s})(\mathbf{o}, \mathbf{n_s})}. \quad (1)$$

Where D is the SGGX distribution [Heitz et al. 2015] centered in the fiber tangent $\mathbf{t}(x)$ distribution, $k^{r,s}$ is the albedo, and G^r is the attenuation defined as

$$G^r(x, \mathbf{i}, \mathbf{o}) = \frac{1 - e^{-T(\Lambda(\mathbf{i},x)+\Lambda(\mathbf{o},x))}}{\Lambda(\mathbf{i}, x) + \Lambda(\mathbf{o}, x)}, \quad (2)$$

with Λ the Smith shadowing/masking function.

The diffuse reflection term $f^{r,d}$, on the other hand, approximates multiple scattering inside yarns, and is defined as

$$f^{r,d}(x, \mathbf{i}, \mathbf{o}) = w \frac{k^{r,d}(x) \langle \mathbf{i} \cdot \mathbf{n_p}(x) \rangle}{\pi \langle \mathbf{i} \cdot \mathbf{n_s} \rangle} + (1 - w) \frac{k^{r,d}(x)}{\pi}, \quad (3)$$

with $k^{r,d}(x)$ the diffuse albedo, $\mathbf{n_s}$ is the normal at the surface, and w blends between the two terms in the sum.

Surface Transmission. The specular tranmission term $f^{t,s}$ is defined following the SpongeCake model, as

$$f^{t,s}(x, \mathbf{i}, \mathbf{o}) = \frac{k^{t,s}(x) D(\mathbf{h}, x) G(\mathbf{i}, \mathbf{o}, x)}{4(\mathbf{i}, \mathbf{n_s})(\mathbf{o}, \mathbf{n_s})}, \quad (4)$$

where G^t is the transmission attenuation defined as

$$G^t(\mathbf{i}, \mathbf{o}, x) = \frac{1 - e^{-T(\Lambda(\mathbf{i},x)+\Lambda(\mathbf{o},x))}}{\Lambda(\mathbf{i}, x) + \Lambda(\mathbf{o}, x)} e^{T\Lambda(\mathbf{o},x)}. \quad (5)$$

Finally, the diffuse transmission $f^{t,d}$term is derived analogously to its reflection counterpart as

$$f^{t,d}(\mathbf{i}, \mathbf{o}, x) = w \frac{k^{t,d}(x) \langle -\mathbf{i} \cdot \mathbf{n_p}(x) \rangle}{\pi \langle -\mathbf{i} \cdot \mathbf{n_s} \rangle} + (1 - w) \frac{k^{t,d}(x)}{\pi}. \quad (6)$$

2 MORE RESULTS AND COMPARISONS

Single-ply vs. multi-ply yarns. The lowest level geometric construction of our method is at ply-level. So our method can naturally represent cloth with both single- and multi-ply yarns, as demonstrated in In Fig. 1. Note how the multi-ply yarn exhibits rich variations with its broken up highlights.

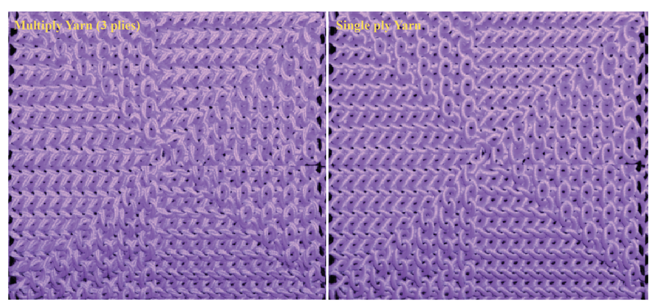

Figure 1: Comparison of the rendering results between multi-ply yarn (3-ply) and single-ply yarn with the same knitted pattern (rendered with 128 SPP, roughness $\sigma = 0.2$ and with a ply twist of $15°$). In addition, in this figure, we demonstrate our method for rendering a more complex knitted pattern, the input maps size is 1024×1024.

Comparison with other surface-based cloth rendering methods. In Fig. 2, we compared our method with other typical surface-based cloth rendering methods under different lighting conditions. Under *frontal lighting*, compared to the methods at ply (or yarn) level [Jin et al. 2022; Irawan and Marschner 2012], our method, incorporating shadowing-masking effect between plies and yarns, shows more visible pattern structure and more natural grazing appearance.

While the model of Sadeghi et al. [2013] also considers shadowing-masking, it is a far-field model and falls short on demonstrating fine geometric details compared to the other methods including ours. More importantly, our method is the only surface-based method that realizes transmission for cloth, enabling the correct rendering of cross highlights under *back lighting*. It's worth noting that, accounting for transmission benefits the scens with *frontal lighting* as well, as our method can evidently render color bleeding on the base of the lamp correctly in the *smooth front lit* scene.

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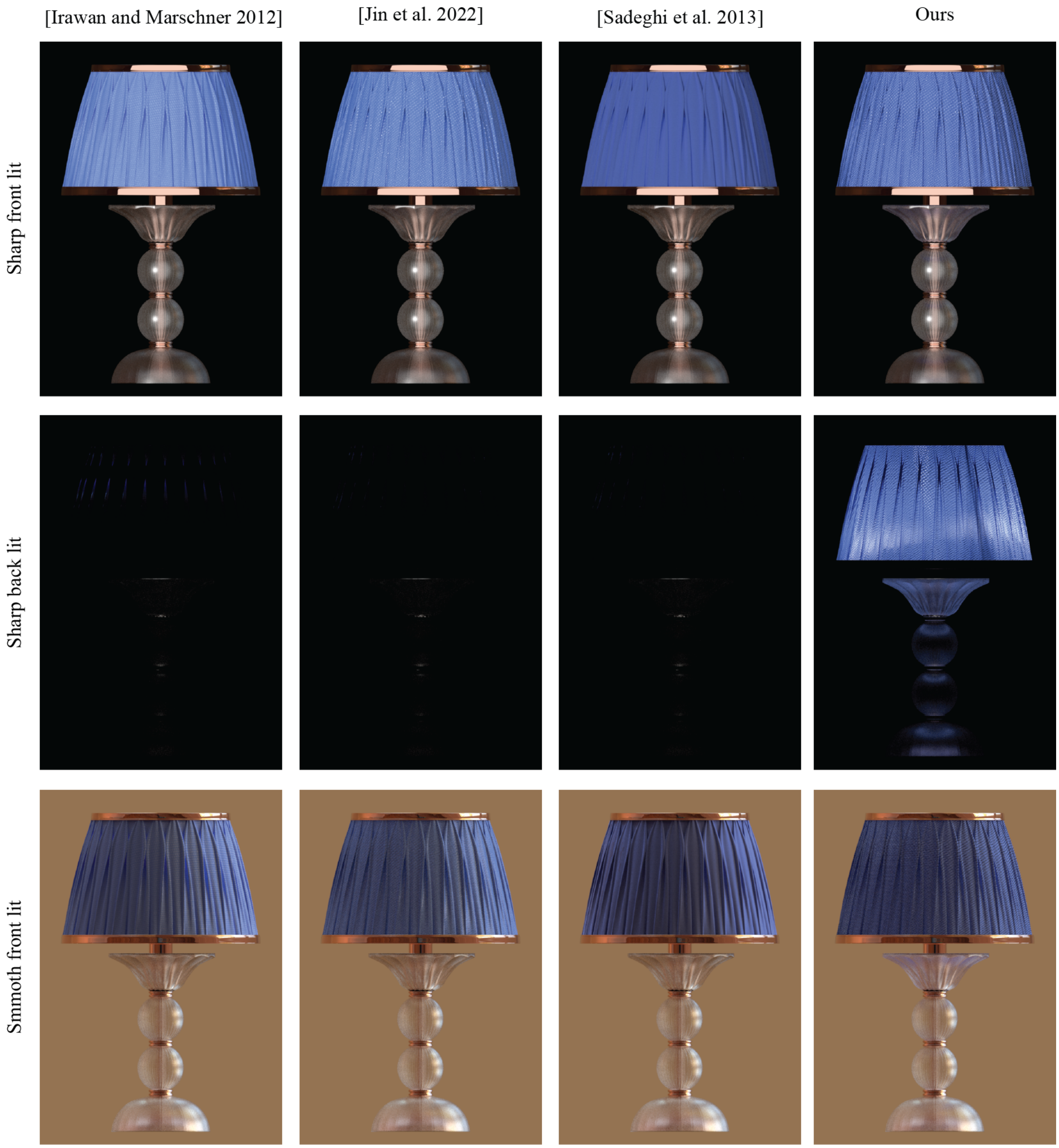

Figure 2: Render comparison with other surface-based methods under different lighting conditions on a lamp with cloth shade. All images are rendered at 128 SPP with roughness $\sigma = 0.07$.

Table 1: Statistics for the scenes in the Supplemental, and performance break-down. We report samples per pixel (SPP), precomputation time (Pre) for both the $A_{\mathcal{G}}$ term and visibility (V), and render time.

Scene	Pre ($A_{\mathcal{G}}$)	Pre (V)	Render Ours	Render [Irawan and Marschner 2012]	Render [Jin et al. 2022]	Render [Sadeghi et al. 2013]
Fig. 1 (multiply)	17 s	26 s	0.7 min	N/A	N/A	N/A
Fig. 1 (single ply)	17 s	24 s	0.7 min	N/A	N/A	N/A
Fig. 2 (sharp front lit)	3 s	6 s	1.2 min	1.9 min	1.4 min	2.0 min
Fig. 2 (sharp back lit)	3 s	6 s	0.7 min	1.1 min	0.7 min	1.8 min
Fig. 2 (smooth front lit)	3 s	6 s	1.3 min	2.0 min	1.5 min	2.0 min