A Heterogeneous Subsurface Scattering Representation Based on Compact and Efficient Matrix Factorization

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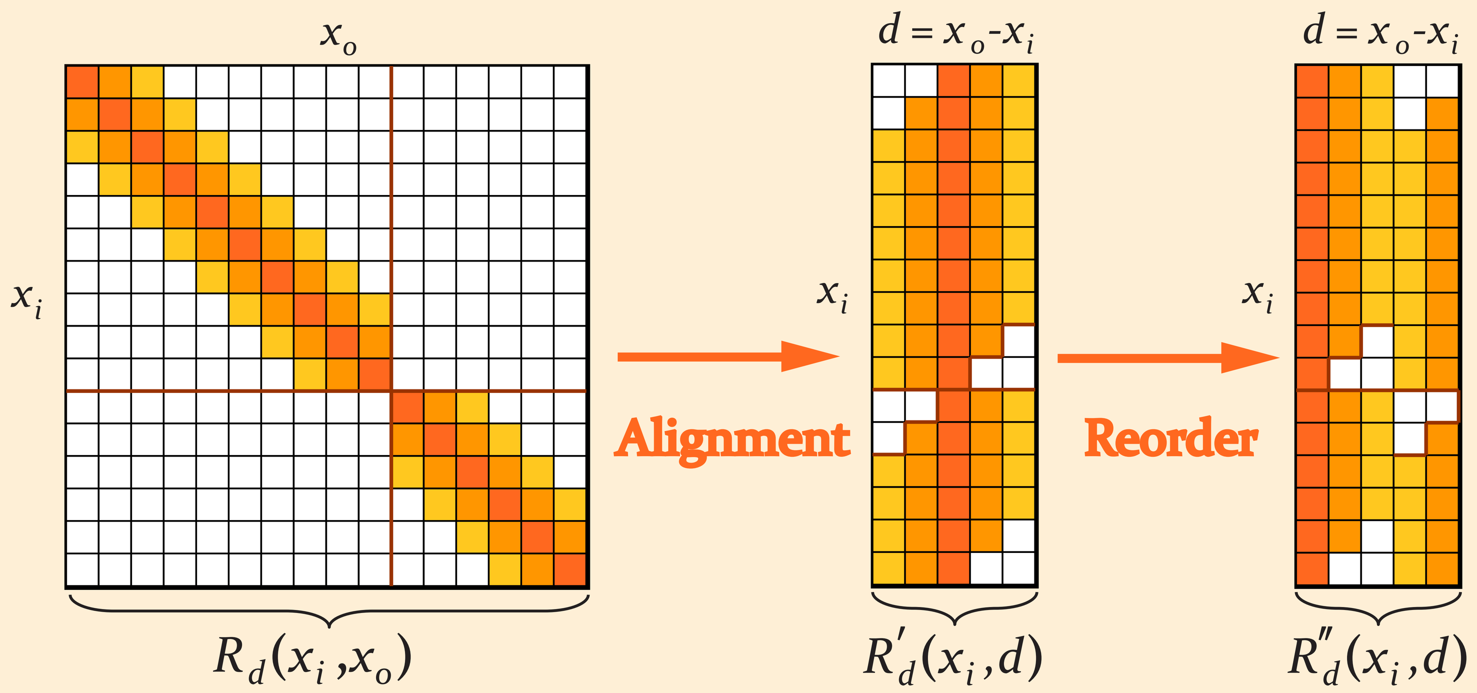
Abstract

This poster presents a novel compact and efficient factored subsurface scattering representation for heterogeneous translucent materials. Our subsurface scattering representation consists of two parts, namely, a matrix factorization and a linear regression method. We first apply a matrix factorization method on the intensity profiles of the heterogeneous subsurface scattering responses. Next, we fit a polynomial model for characterizing the differences between the different color channels with a linear regression procedure. We validate our heterogeneous subsurface scattering representation on various real-world heterogeneous translucent materials, geometries and lighting conditions. We show that our method provides good compression at acceptable visual accuracy.

Subsurface Scattering Model



Factorization: For an efficient and compact factorization, we apply the error modeling approach using the Tucker factorization [1] to $R''_d(x_i, d)$ matrix. Please refer to [2] for an in depth discussion on the error modeling approach:

$$R''_d(x_i, d) \approx \sum_{j=1}^{T} g_j f_j(x_i) h_j(d), \tag{1}$$

Linear Regression: In the linear regression procedure, we estimate the linear coefficients for each row of measured subsurface scattering matrix. Then, the corresponding models for each color channel can be written as

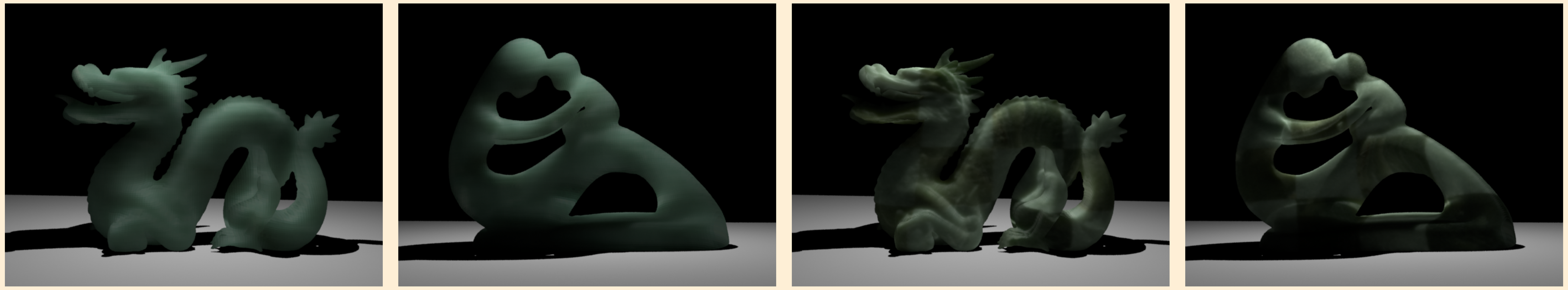
$$R_{dr}(x_i, x_o) \approx \sum_{p=0}^{P} \beta_{rpx_i} R'_d(x_i, d)^p, \tag{2}$$

$$R_{dg}(x_i, x_o) \approx \sum_{p=0}^{P} \beta_{gpx_i} R'_d(x_i, d)^p, \tag{3}$$

$$R_{db}(x_i, x_o) \approx \sum_{p=0}^{P} \beta_{bpx_i} R'_d(x_i, d)^p, \tag{4}$$

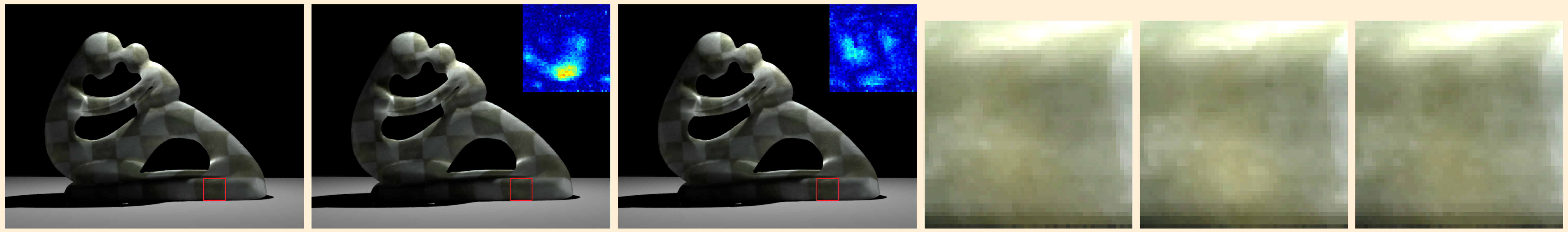
Results

To visualize our results, we implemented a rendering scheme similar to Peers et al. [3] in the Mitsuba rendering system [4]. We verified our Tucker factorization based subsurface scattering model on several real-world subsurface scattering materials, ranging from fairly homogeneous to highly translucent heterogeneous materials. As can be seen in the following figures, our Tucker-based subsurface scattering model can be used with any geometries, while providing heterogeneous subsurface scattering effects visually plausibly.



(a) (b) (c) (d)

Representing heterogeneous subsurface scattering with our factored model. (a)-(b) marble (close up) material ($T = 15, P = 4$), (c)-(d) chessboard (4×4) material ($T = 15, P = 7$).



(a) (Data size: 2.75 GB) (b) (Data size: 10.8 MB) (c) (Data size: 10.2 MB) (d) (e) ($RMSE = 0.0384$) ($PSNR = 29.65$) (f) ($RMSE = 0.0242$) ($PSNR = 31.16$)

For visual comparison on a statue under spot lighting, (a) a heterogeneous chessboard (8×8) was rendered with a full Monte Carlo path tracing algorithm (reference image); (b) and (c) were rendered using Peers et al. [3] and our factored subsurface scattering model, respectively. (d), (e), and (f) are zoom-in images from (a), (b), and (c), respectively. For better comparison, false-color differences were scaled by a factor of 5.

References

[1] L.R. Tucker. Some Mathematical Notes on Three-mode Factor Analysis, *Psychometrika 31*, 3 (Sept. 1966), 279-311.

[2] A. Bilgili, A. Öztürk, M. Kurt. A General BRDF Representation Based on Tensor Decomposition, *Computer Graphics Forum 30*, 8 (December 2011), 2427-2439.

[3] P. Peers, K. vom Berge, W. Matusik, R. Ramamoorthi, J. Lawrence, S. Rusinkiewicz, P. Dutré. A Compact Factored Representation of Heterogeneous Subsurface Scattering, *ACM TOG 25*, 3 (July 2006), 746-753. (Proc. SIGGRAPH '06).

[4] W. Jakob. Mitsuba Renderer, 2013. http://www.mitsuba-renderer.org.

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