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RESEARCH REPORT

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Bidirectional Texture Function Compression Based on Multi-Level Vector Quantization SUPPLEMENTAL MATERIAL

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Bidirectional Texture Function Compression Based on Multi-Level Vector Quantization

SUPPLEMENTAL MATERIAL

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Abstract

The Bidirectional Texture Function (BTF) is becoming widely used for accurate representation of real-world material appearance. In this paper a novel BTF compression model is proposed. The model resamples input BTF data into a parametrization, allowing decomposition of individual view and illumination dependent texels into a set of multidimensional conditional probability density functions. These functions are compressed in turn using a novel multi-level vector quantization algorithm. The result of this algorithm is a set of index and scale code-books for individual dimensions. BTF reconstruction from the model is then based on fast chained indexing into the nested stored code-books. In the proposed model, luminance and chromaticity are treated separately to achieve further compression. The proposed model achieves low distortion and compression ratios $1:233-1:2040$, depending on BTF sample variability. These results compare well with several other BTF compression methods with predefined compression ratios, usually smaller than $1:200$. We carried out a psychophysical experiment comparing our method with LPCA method. BTF synthesis from the model was implemented on a standard GPU, yielded interactive framerates. The proposed method allows the fast importance sampling required by eye-path tracing algorithms in image synthesis.

This document provides supplemental material to the paper:

Havran V., Filip J., Myszkowski K.,
Bidirectional Texture Function Compression Based on Multi-Level Vector Quantization
Computer Graphics Forum, 2010.

1 Method

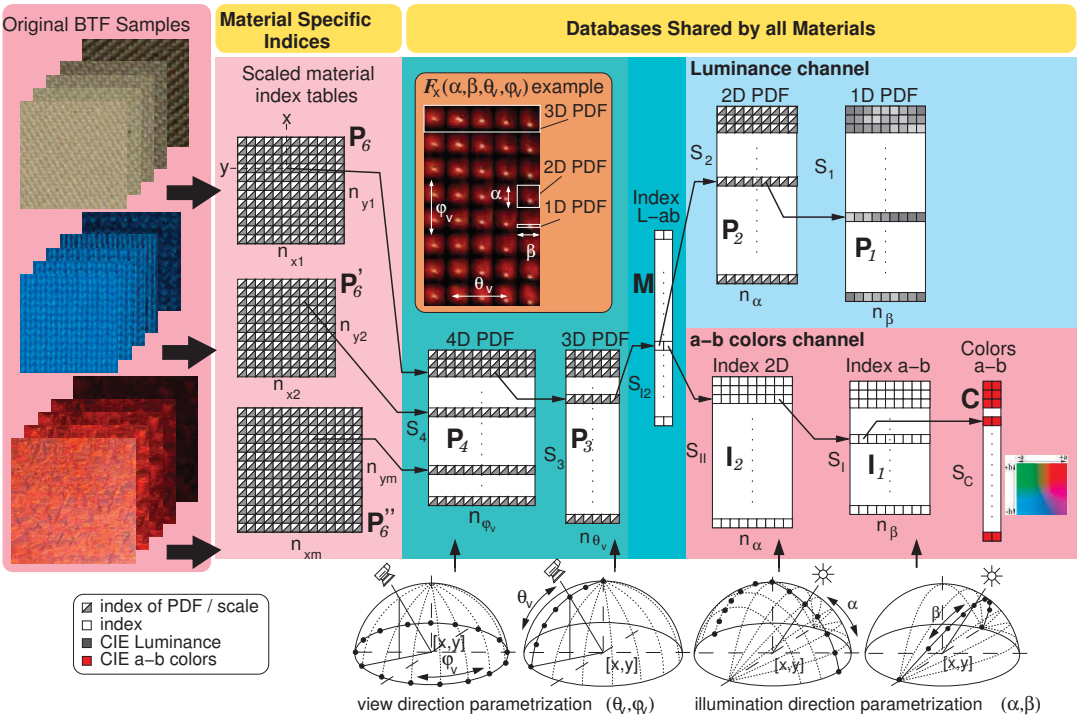


Figure 1: The proposed BTF model scheme illustrating dependencies of individual VQ code-books.

The scheme of the proposed BTF compression model is shown in Fig. 1. The compression scheme is based on subsequent decomposition of 4D, 3D, 2D, and 1D dimensional slices of BTF data. These slices are obtained by resampling original BTF data to a novel parametrization of

illumination and viewing directions. The model's compression is achieved by vector quantization of slices to individual dimensions to obtain a set of code-books. These code-books work as nested look-up tables of indices and scales of the individual slices while only the code-books at the lowest level contain the resampled original BTF data. For more information please refer to the original paper.

2 Contents

- **Pages 3-38: BTF Model Renderings:** Comparison of original BTF renderings and those from the proposed model for point-light and grace environment (using images, similarity measures, and VDPs)

- **Pages 39-54: Proposed Method Comparison with Existing BTF Compression Methods:** Comparison of performance of the proposed method with three reference BTF compression methods (based on both single rendered image and whole BTF dataset).

- **Pages 55:** Comparison of the proposed method performance on HDR BTF samples.

- **Pages 56-58: Apparent BRDFs Comparison:** Examples of original and modelled PDF4D slices of BTF data. PDF4D slice shows decomposition of single view and illumination pixel in proposed data parametrization.

3 BTF Model Renderings

This section contains rendered results of the proposed BTF compression model. Each page consists of original BTF data rendering (the first and the third row) compared with the proposed BTF model rendering (the second and the fourth row). The first two row shows three different 3D models: sphere, tablecloth, and bunny illuminated by a single point light, the last two rows shows the same models illuminated by a grace[1] environment .

All couples of original and models renderings are accompanied by their difference expressed using:

- MSSIM_W - weighted MSSIM [Wang et al. 2004] computed in YCrCb color-space with weights (Y: 0.8, Cr: 0.1, Cb: 0.1).

- MSSIM_Y - weighted MSSIM computed in Luminance channel Y of YCrCb color-space.

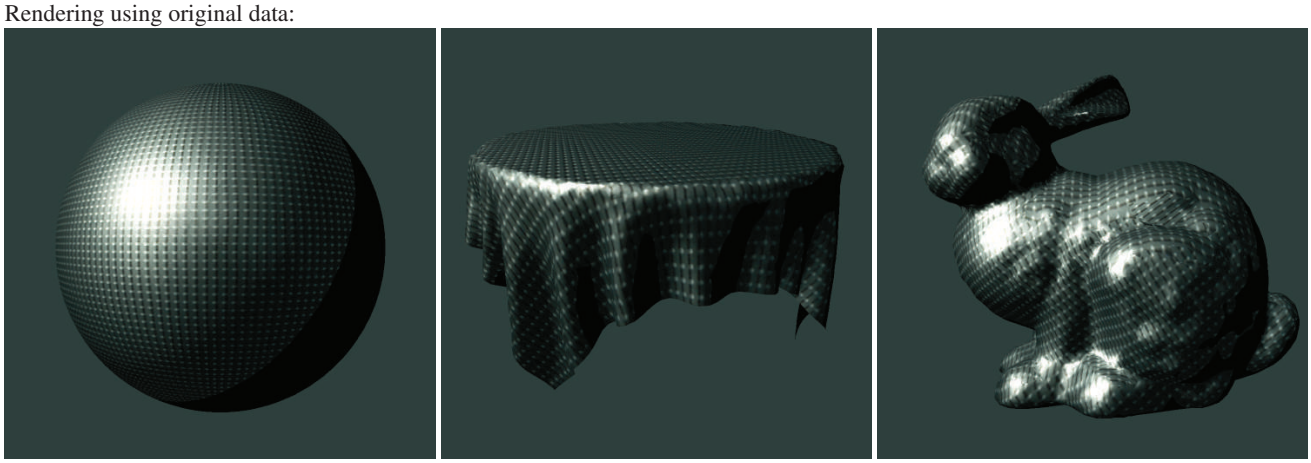
- $\Delta\hat{E}$ - is average difference in CIE LAB color-space computed over all pixels.

- VDP - results of visual difference predictor [Mantiuk et al. 2004], showing perceptual difference between original and proposed images for screen size 37.5×30cm, resolution 1280×1024 pixels, observer distance 0.7m, and screen luminance 80cd/m^2.

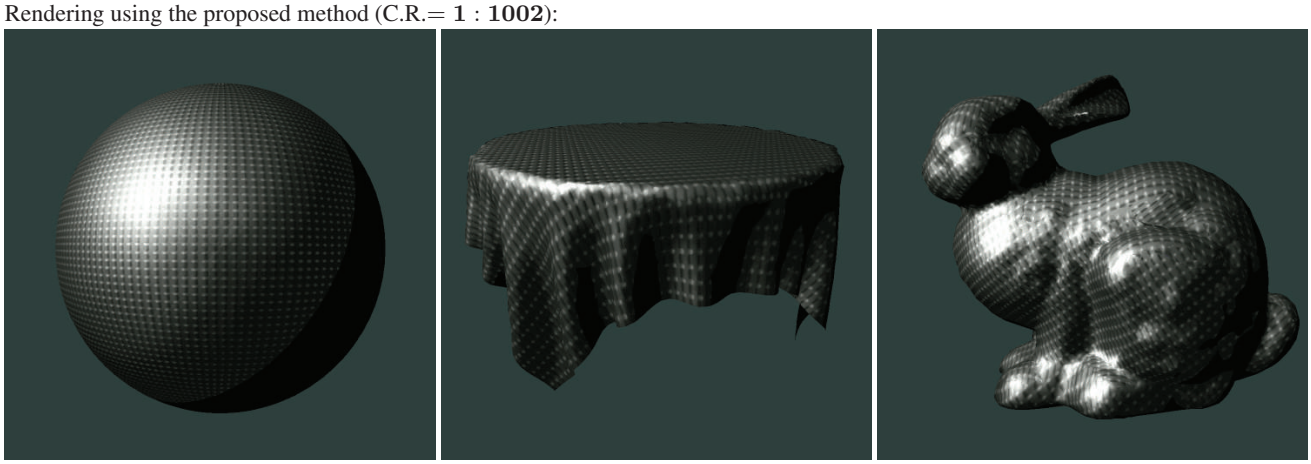
[1] http://www.debevec.org

Figure 2: BTF sample **alu** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 1002}$):



$\text{MSSIM}_W = 0.9712$	$\text{MSSIM}_W = 0.9782$	$\text{MSSIM}_W = 0.9734$
$\text{MSSIM}_Y = 0.9644$	$\text{MSSIM}_Y = 0.9729$	$\text{MSSIM}_Y = 0.9671$
$\Delta\hat{E}_{LAB} = 1.63$	$\Delta\hat{E}_{LAB} = 1.26$	$\Delta\hat{E}_{LAB} = 1.55$
VDP:	VDP:	VDP:

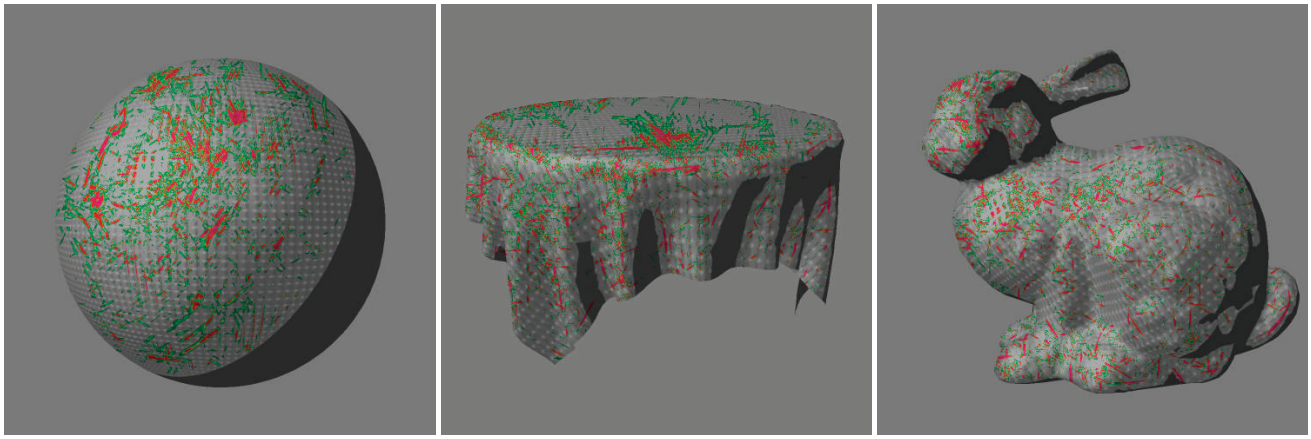
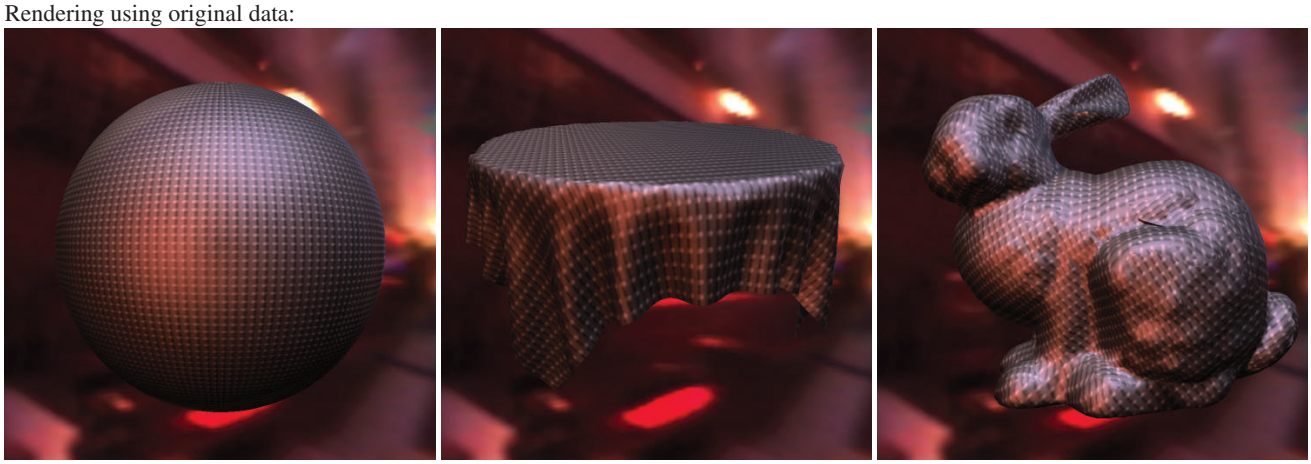
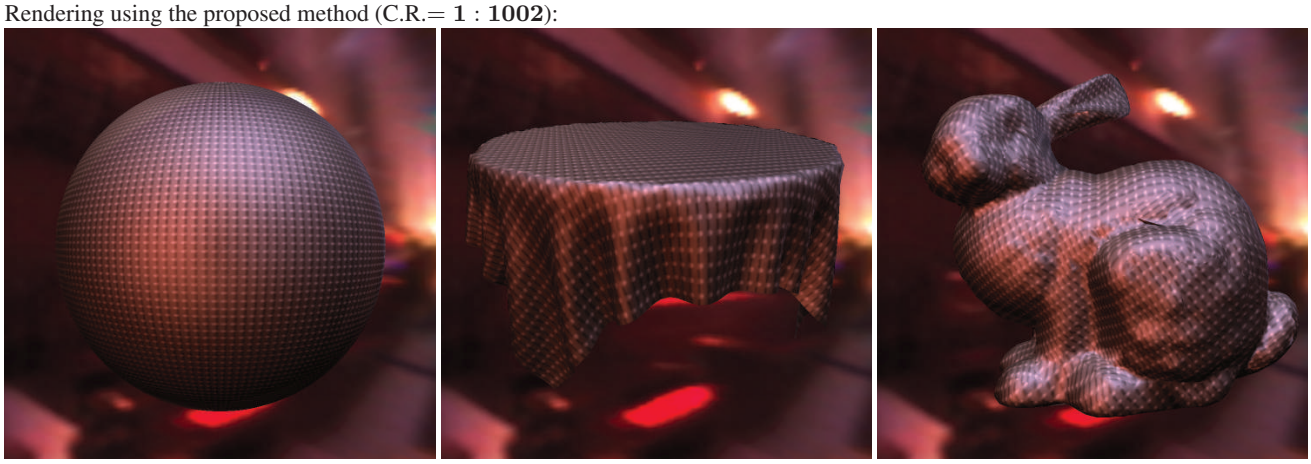


Figure 3: BTF sample **alu** for **grace** environment.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 1002}$):



$\text{MSSIM}_W = 0.9908$	$\text{MSSIM}_W = 0.9894$	$\text{MSSIM}_W = 0.9910$
$\text{MSSIM}_Y = 0.9887$	$\text{MSSIM}_Y = 0.9869$	$\text{MSSIM}_Y = 0.9890$
$\Delta\hat{E}_{LAB} = 1.66$	$\Delta\hat{E}_{LAB} = 1.56$	$\Delta\hat{E}_{LAB} = 1.72$
VDP:	VDP:	VDP:

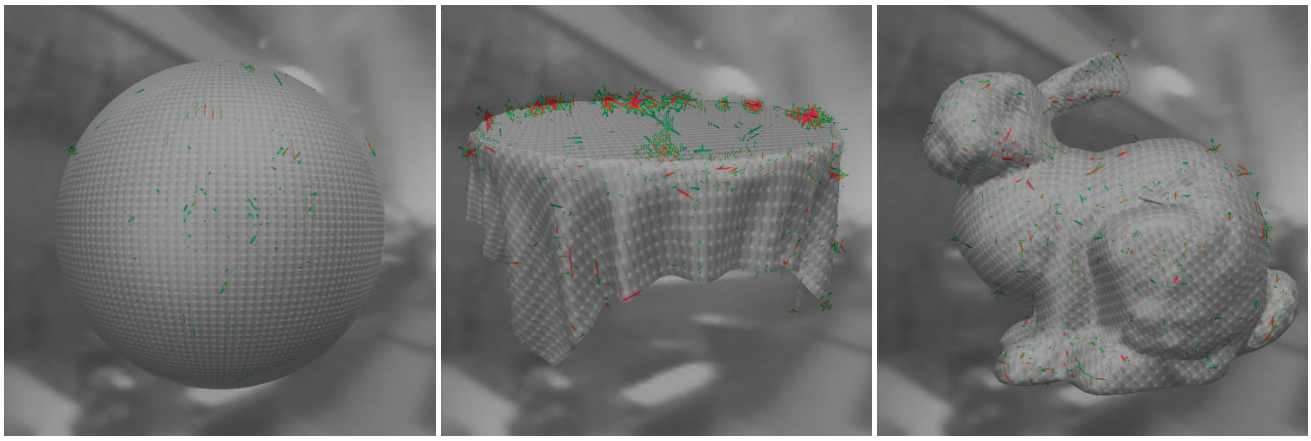
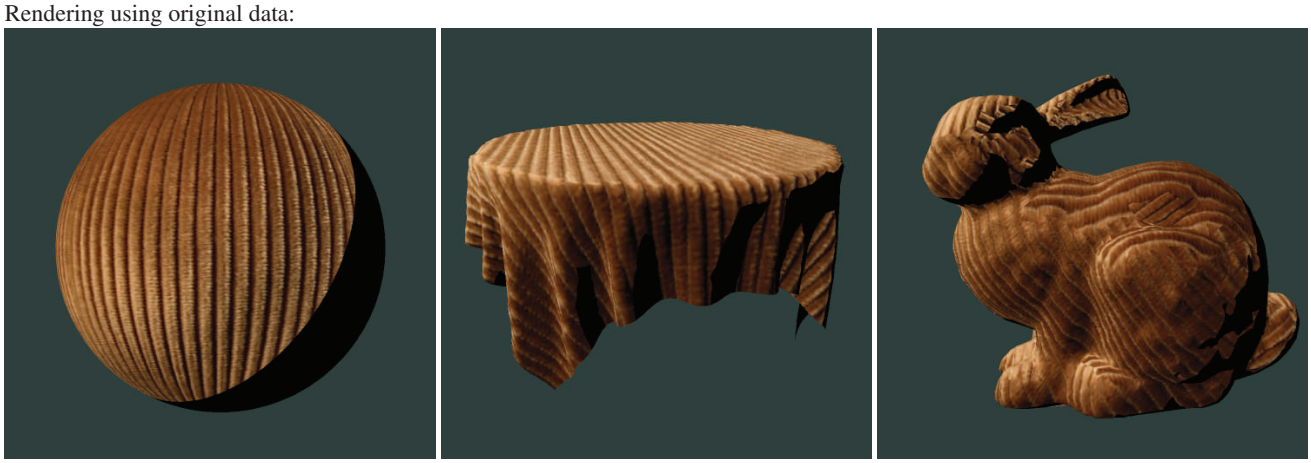
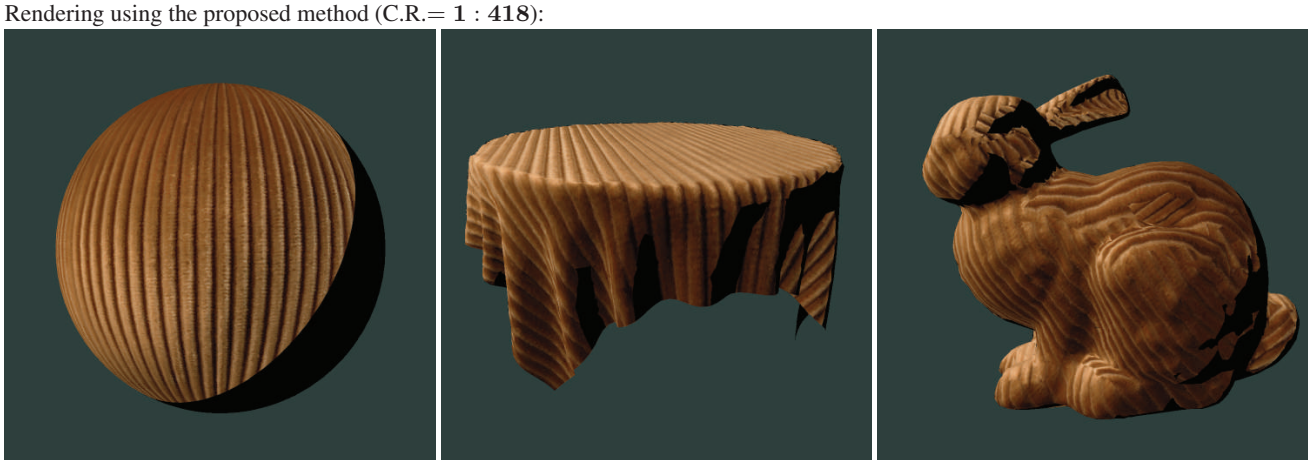


Figure 4: BTF sample **corduroy** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 418}$):



$\text{MSSIM}_W = 0.9326$	$\text{MSSIM}_W = 0.9421$	$\text{MSSIM}_W = 0.9550$
$\text{MSSIM}_Y = 0.9173$	$\text{MSSIM}_Y = 0.9292$	$\text{MSSIM}_Y = 0.9449$
$\Delta\hat{E}_{LAB} = 1.81$	$\Delta\hat{E}_{LAB} = 1.46$	$\Delta\hat{E}_{LAB} = 1.41$
VDP:	VDP:	VDP:

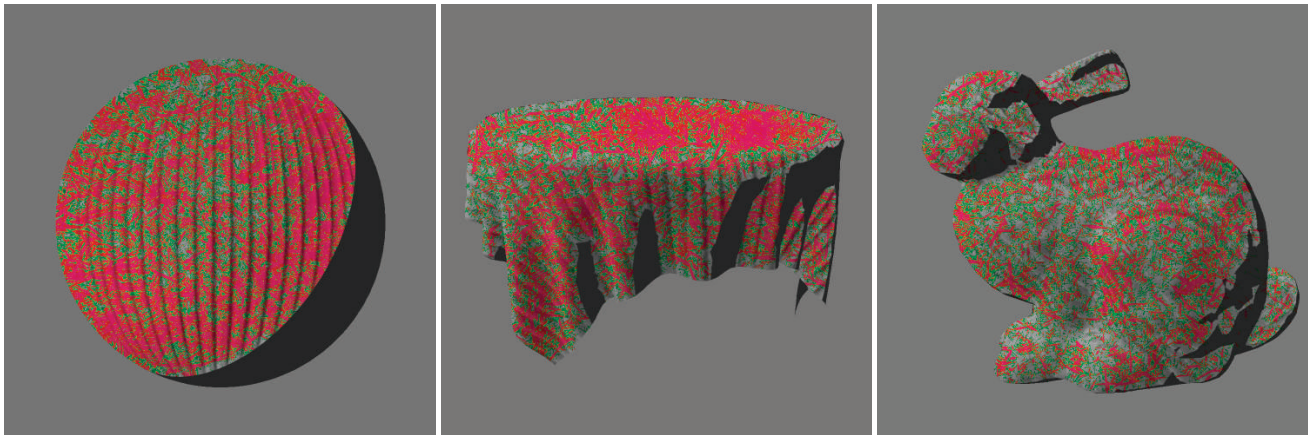
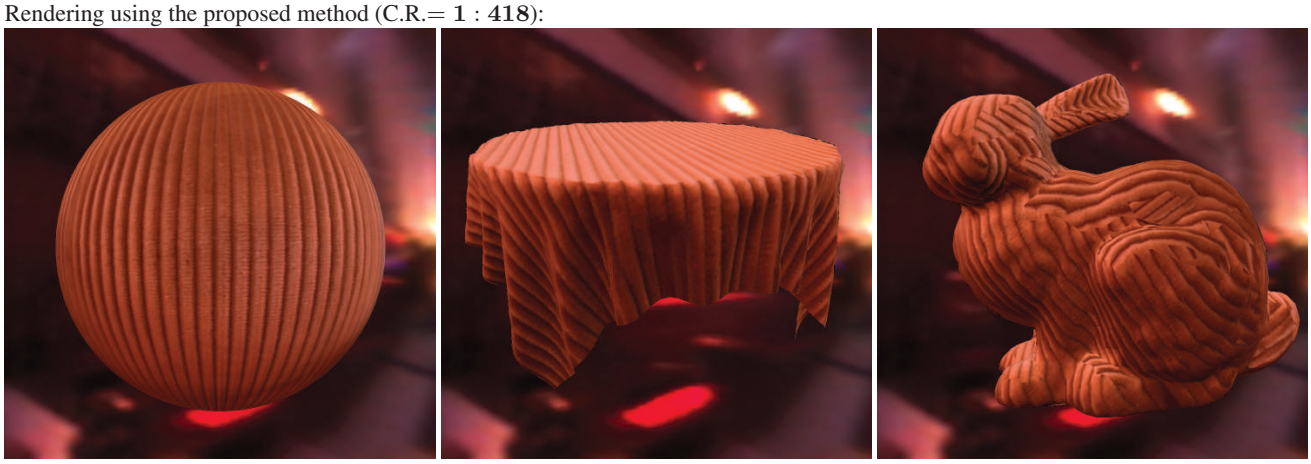


Figure 5: BTF sample **corduroy** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 418}$):



$\text{MSSIM}_W = 0.9583$	$\text{MSSIM}_W = 0.9711$	$\text{MSSIM}_W = 0.9733$
$\text{MSSIM}_Y = 0.9488$	$\text{MSSIM}_Y = 0.9653$	$\text{MSSIM}_Y = 0.9675$
$\Delta\hat{E}_{LAB} = 1.50$	$\Delta\hat{E}_{LAB} = 1.32$	$\Delta\hat{E}_{LAB} = 1.37$
VDP:	VDP:	VDP:

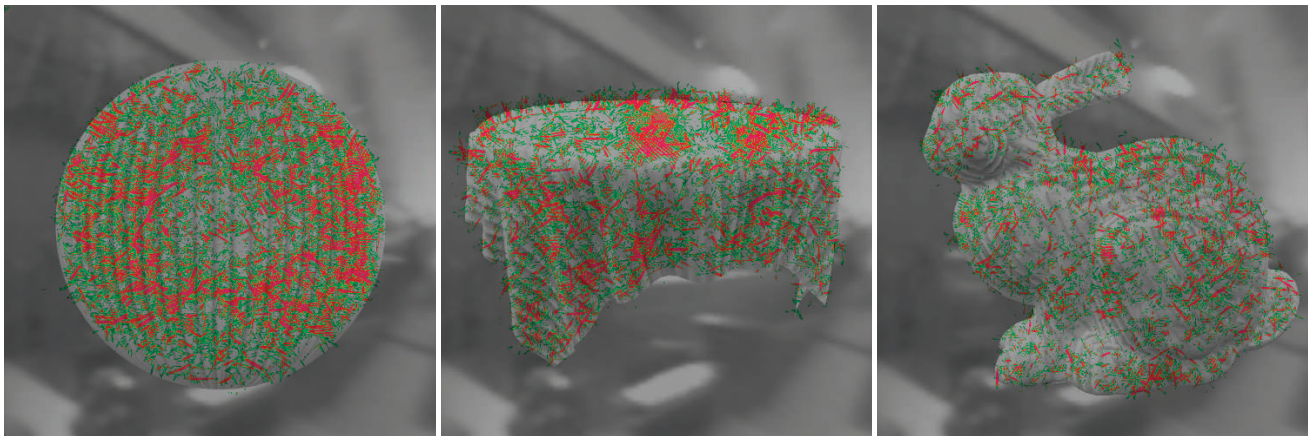
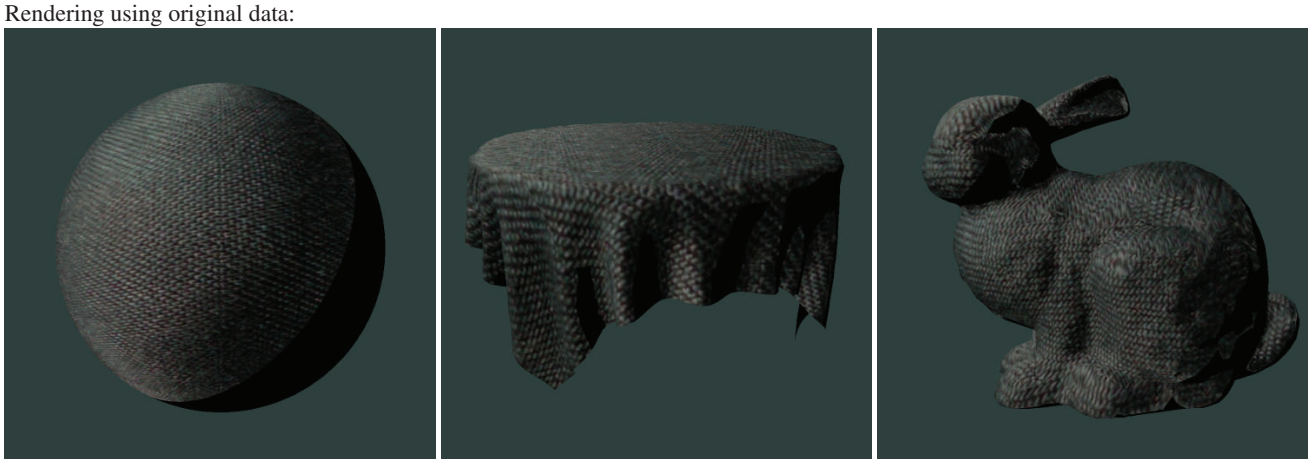
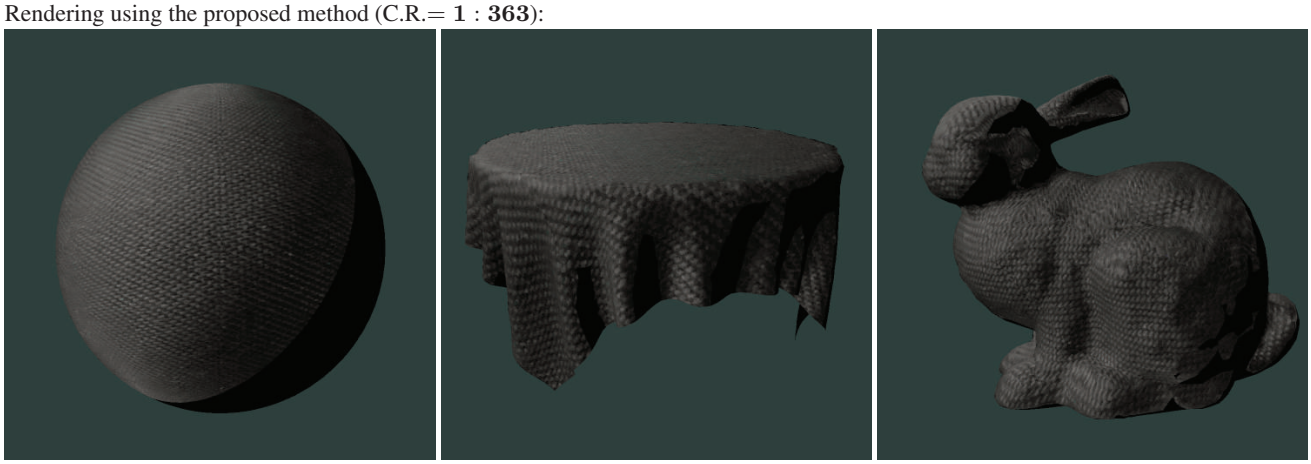


Figure 6: BTF sample **fabric01** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{363}$):



MSSIM$_W = 0.9298$	MSSIM$_W = 0.9372$	MSSIM$_W = 0.9371$
MSSIM$_Y = 0.9125$	MSSIM$_Y = 0.9217$	MSSIM$_Y = 0.9216$
$\Delta\hat{E}_{LAB} = 1.61$	$\Delta\hat{E}_{LAB} = 1.33$	$\Delta\hat{E}_{LAB} = 1.55$
VDP:	VDP:	VDP:

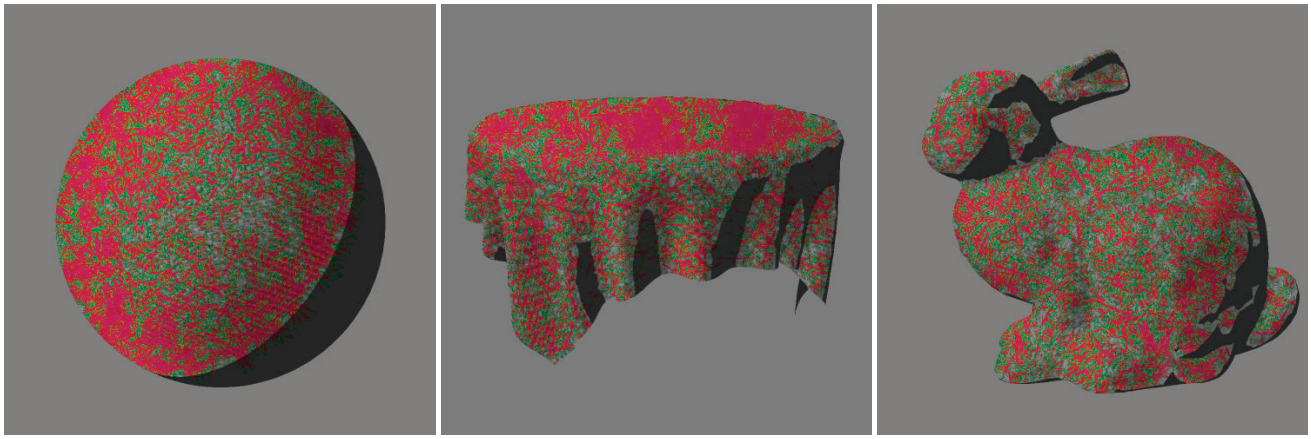
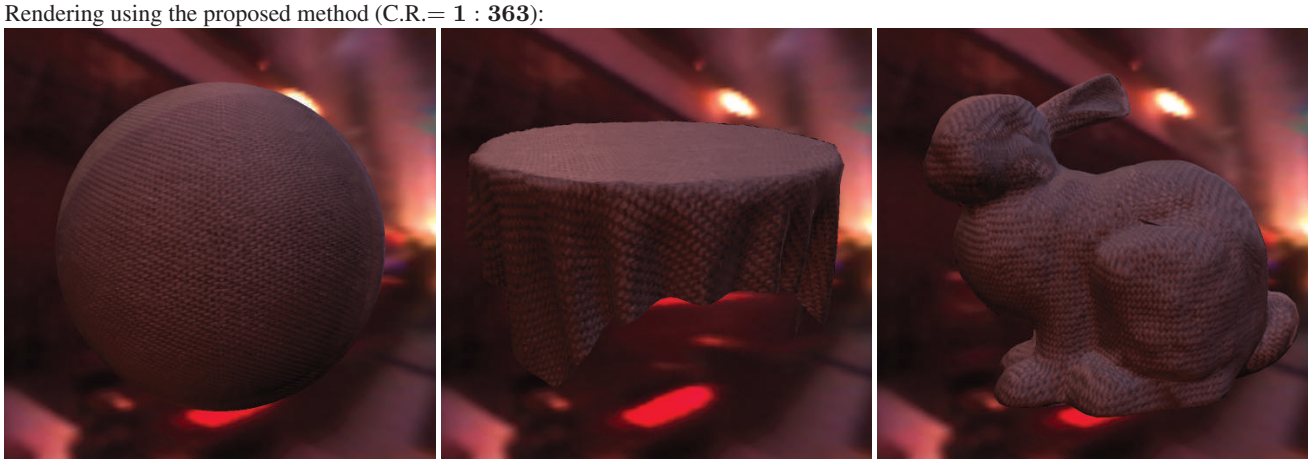


Figure 7: BTF sample **fabric01** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 363}$):



$\text{MSSIM}_W = 0.9644$	$\text{MSSIM}_W = 0.9691$	$\text{MSSIM}_W = 0.9665$
$\text{MSSIM}_Y = 0.9557$	$\text{MSSIM}_Y = 0.9617$	$\text{MSSIM}_Y = 0.9585$
$\Delta\hat{E}_{LAB} = 1.49$	$\Delta\hat{E}_{LAB} = 1.35$	$\Delta\hat{E}_{LAB} = 1.46$
VDP:	VDP:	VDP:

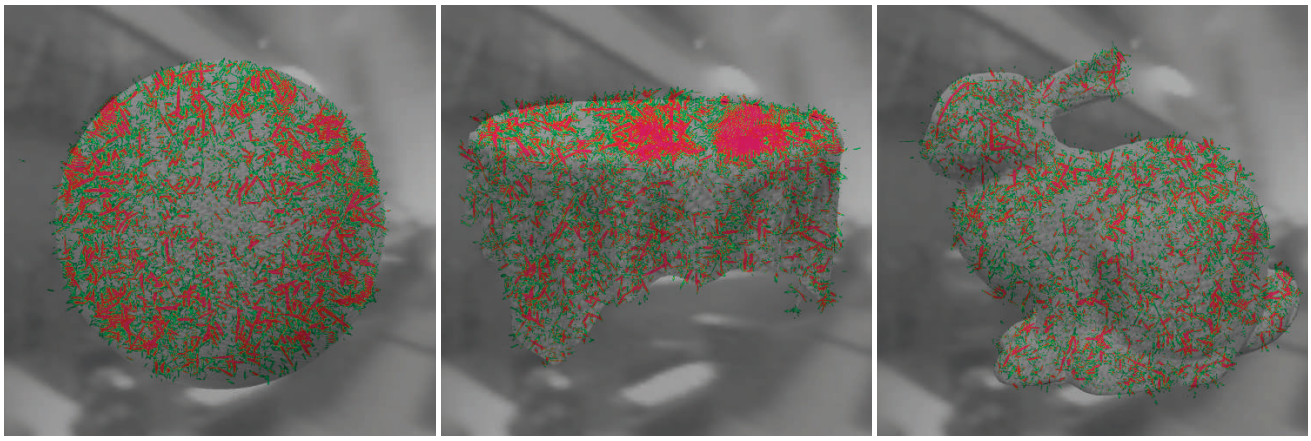
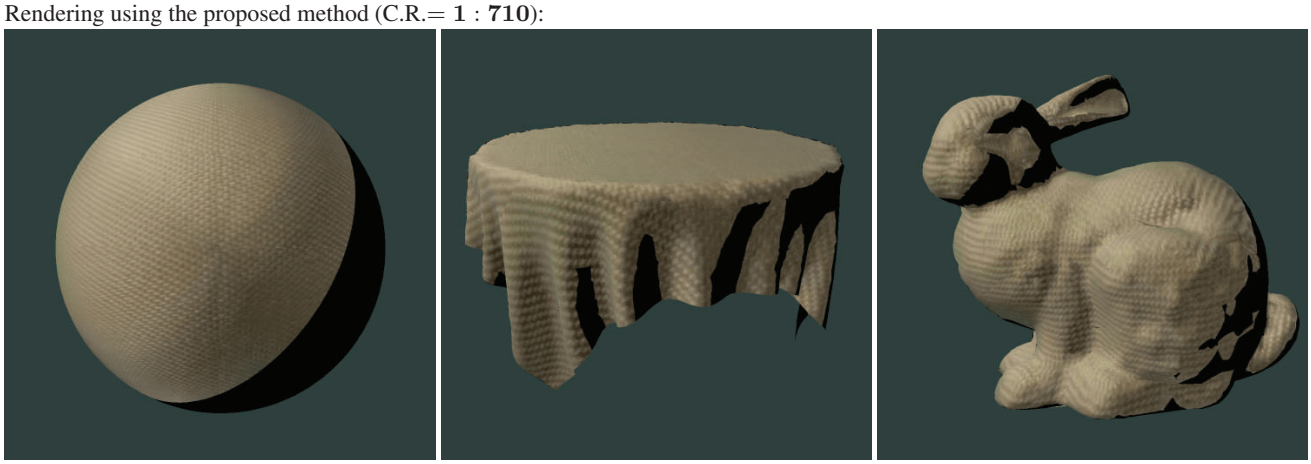


Figure 8: BTF sample **fabric02** for point light from the left.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{710}$):



$\text{MSSIM}_W = 0.9588$	$\text{MSSIM}_W = 0.9672$	$\text{MSSIM}_W = 0.9640$
$\text{MSSIM}_Y = 0.9488$	$\text{MSSIM}_Y = 0.9595$	$\text{MSSIM}_Y = 0.9554$
$\Delta\hat{E}_{LAB} = 1.31$	$\Delta\hat{E}_{LAB} = 1.14$	$\Delta\hat{E}_{LAB} = 1.30$
VDP:	VDP:	VDP:

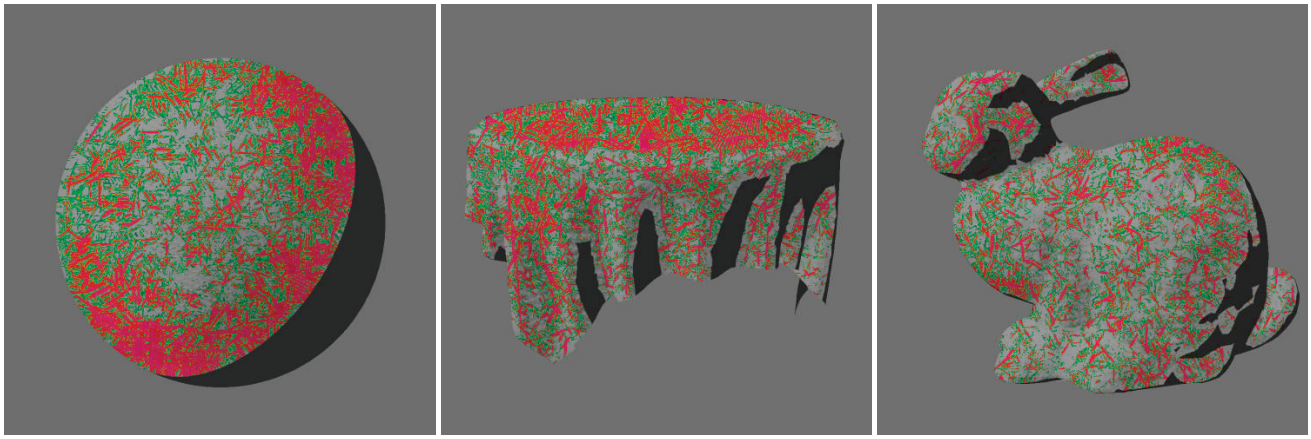
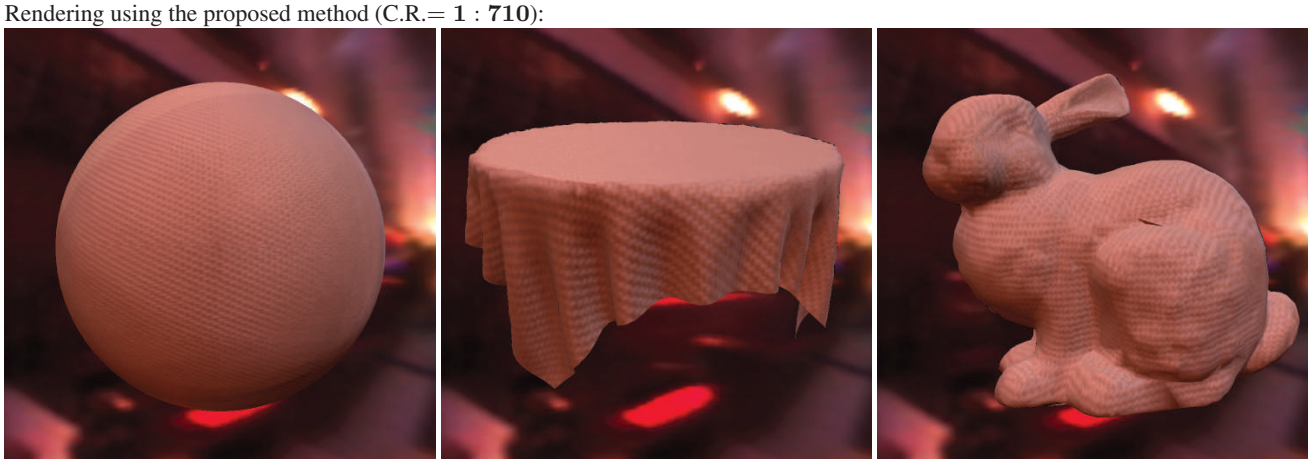


Figure 9: BTF sample **fabric02** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{710}$):



$\text{MSSIM}_W = 0.9863$	$\text{MSSIM}_W = 0.9849$	$\text{MSSIM}_W = 0.9848$
$\text{MSSIM}_Y = 0.9830$	$\text{MSSIM}_Y = 0.9815$	$\text{MSSIM}_Y = 0.9814$
$\Delta\hat{E}_{LAB} = 1.26$	$\Delta\hat{E}_{LAB} = 1.24$	$\Delta\hat{E}_{LAB} = 1.30$
VDP:	VDP:	VDP:

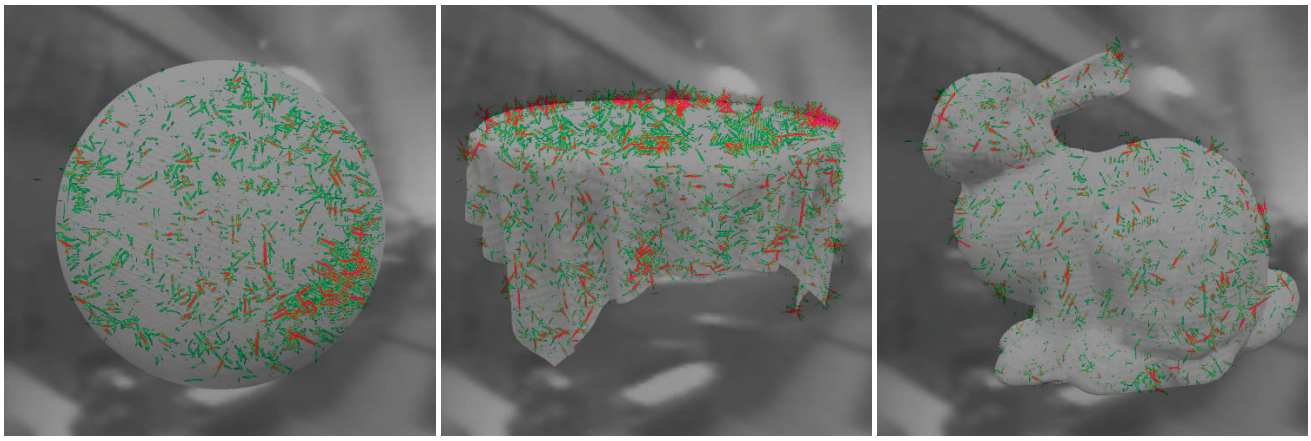
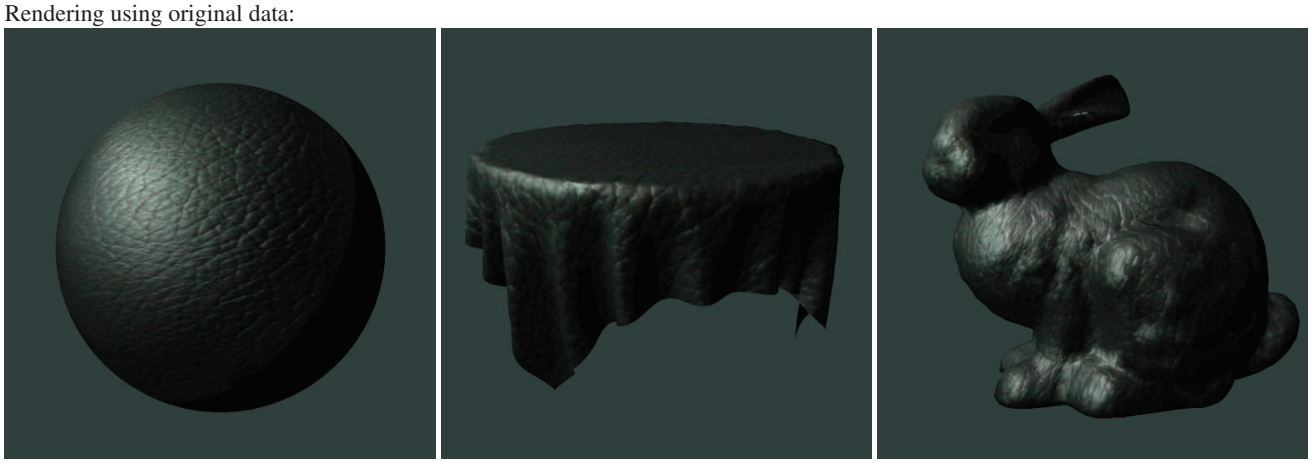
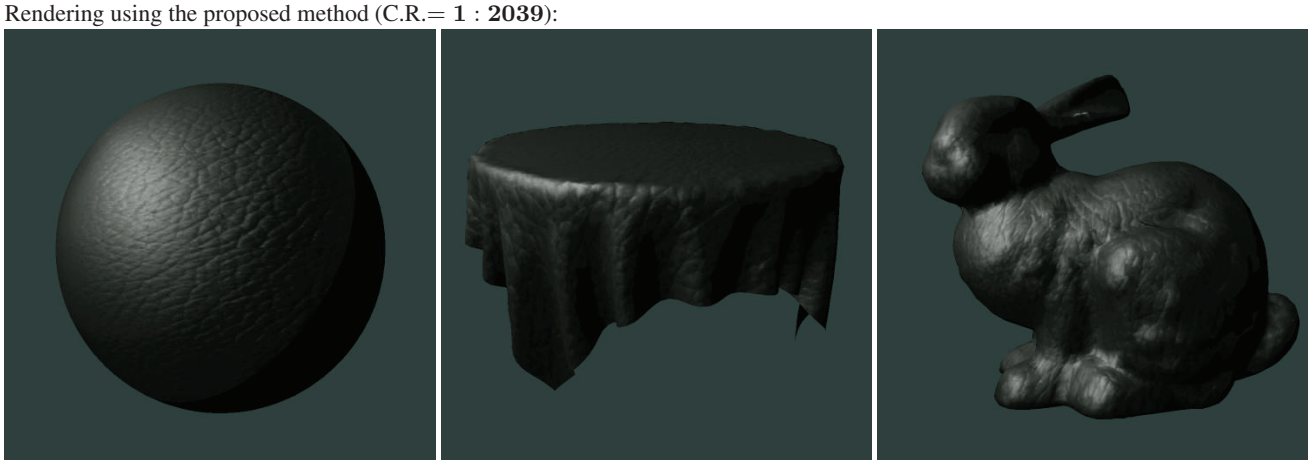


Figure 10: BTF sample **foil01** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 2039}$):



$\text{MSSIM}_W = 0.9706$	$\text{MSSIM}_W = 0.9838$	$\text{MSSIM}_W = 0.9756$
$\text{MSSIM}_Y = 0.9633$	$\text{MSSIM}_Y = 0.9799$	$\text{MSSIM}_Y = 0.9669$
$\Delta\hat{E}_{LAB} = 1.08$	$\Delta\hat{E}_{LAB} = 0.78$	$\Delta\hat{E}_{LAB} = 0.98$
VDP:	VDP:	VDP:

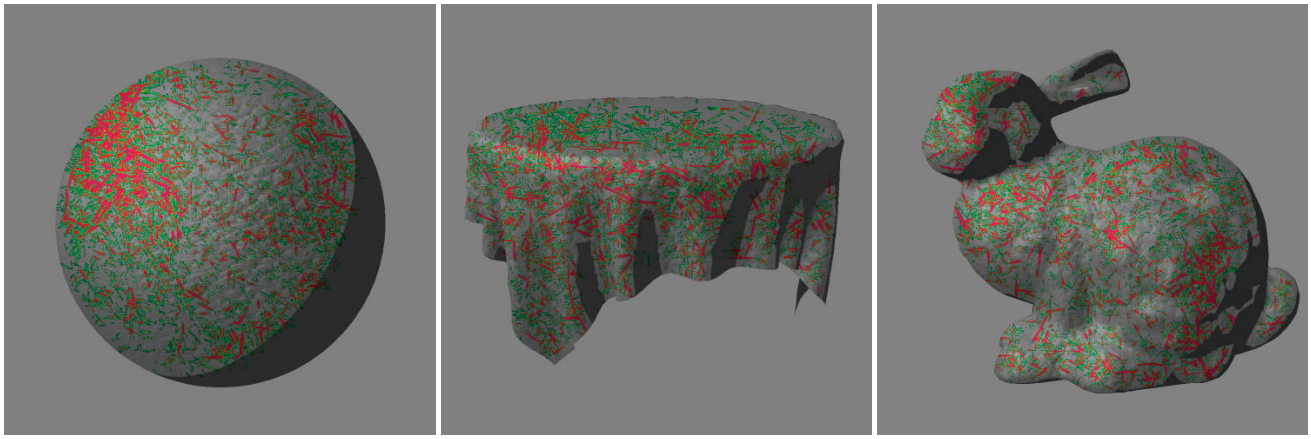
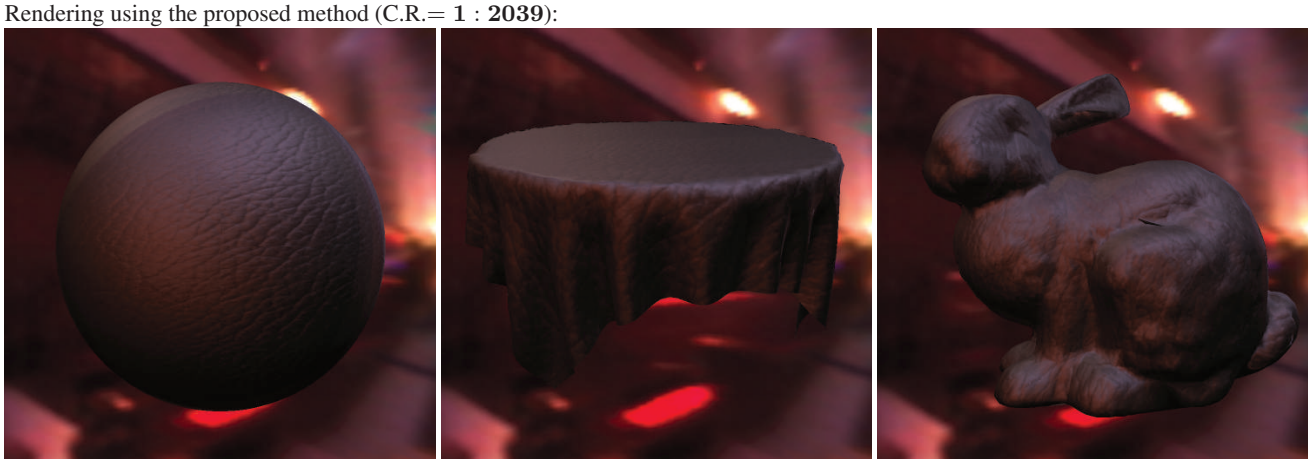


Figure 11: BTF sample **foil01** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 2039}$):



$\text{MSSIM}_W = 0.9909$	$\text{MSSIM}_W = 0.9919$	$\text{MSSIM}_W = 0.9904$
$\text{MSSIM}_Y = 0.9887$	$\text{MSSIM}_Y = 0.9899$	$\text{MSSIM}_Y = 0.9881$
$\Delta\hat{E}_{LAB} = 1.04$	$\Delta\hat{E}_{LAB} = 0.95$	$\Delta\hat{E}_{LAB} = 1.06$
VDP:	VDP:	VDP:

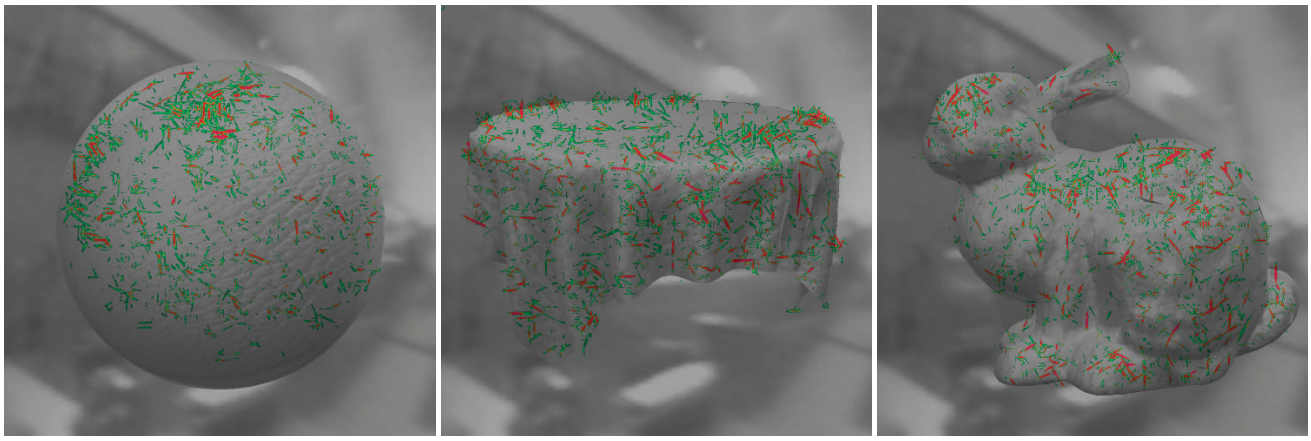
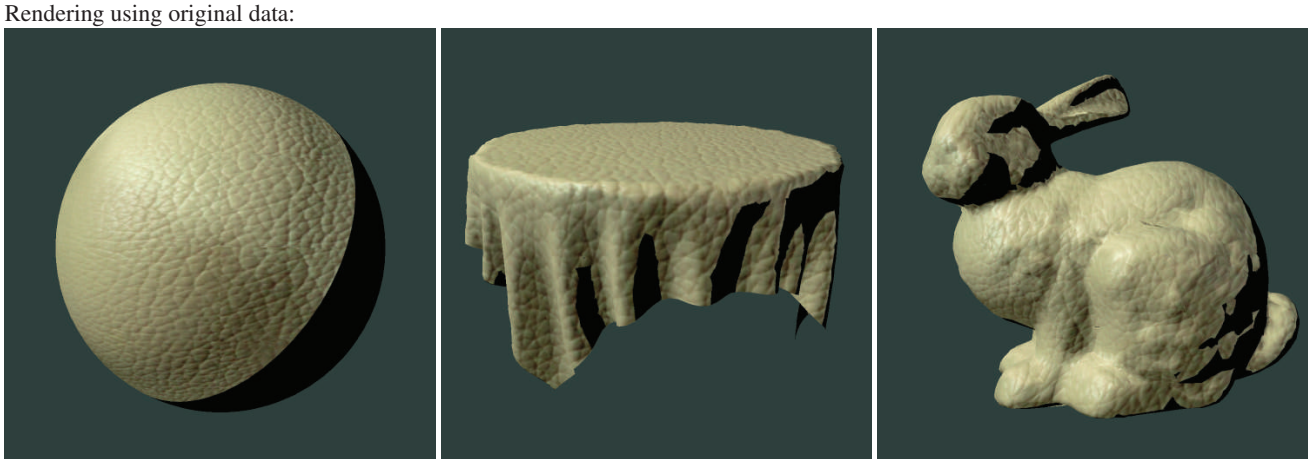
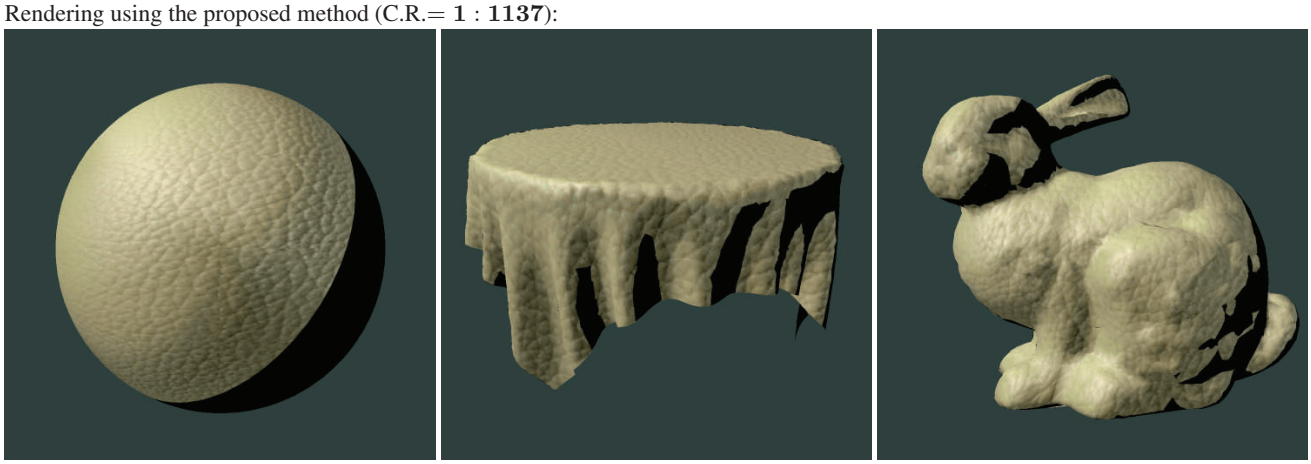


Figure 12: BTF sample **foil02** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 1137}$):



$\text{MSSIM}_W = 0.9548$	$\text{MSSIM}_W = 0.9644$	$\text{MSSIM}_W = 0.9650$
$\text{MSSIM}_Y = 0.9442$	$\text{MSSIM}_Y = 0.9561$	$\text{MSSIM}_Y = 0.9569$
$\Delta\hat{E}_{LAB} = 1.45$	$\Delta\hat{E}_{LAB} = 1.2$	$\Delta\hat{E}_{LAB} = 1.36$
VDP:	VDP:	VDP:

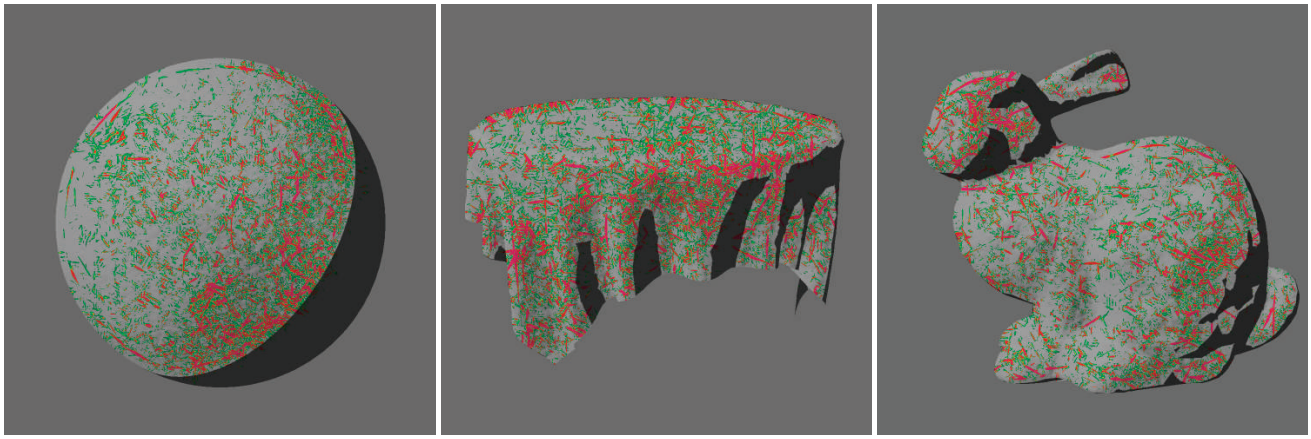
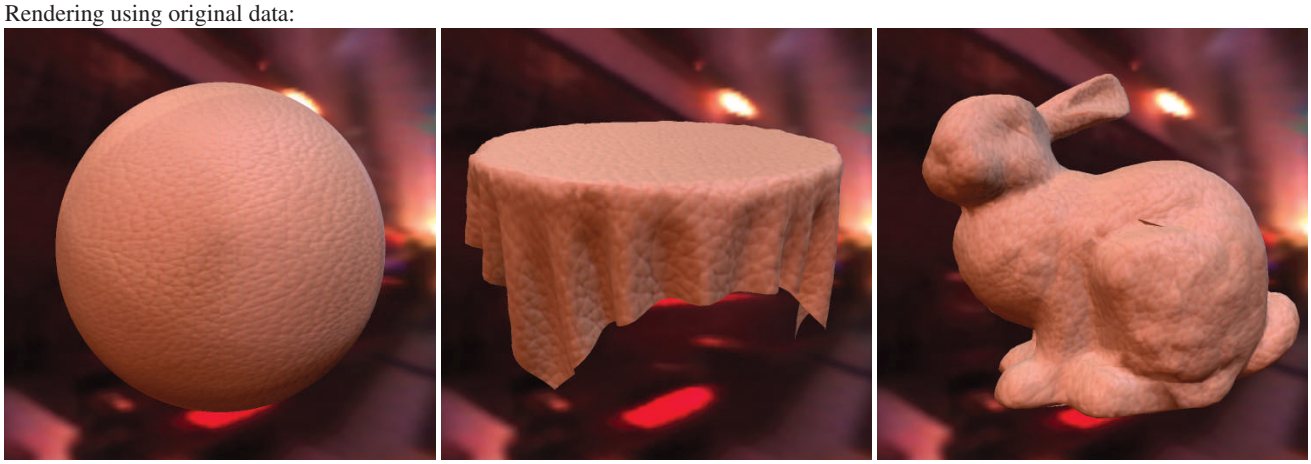
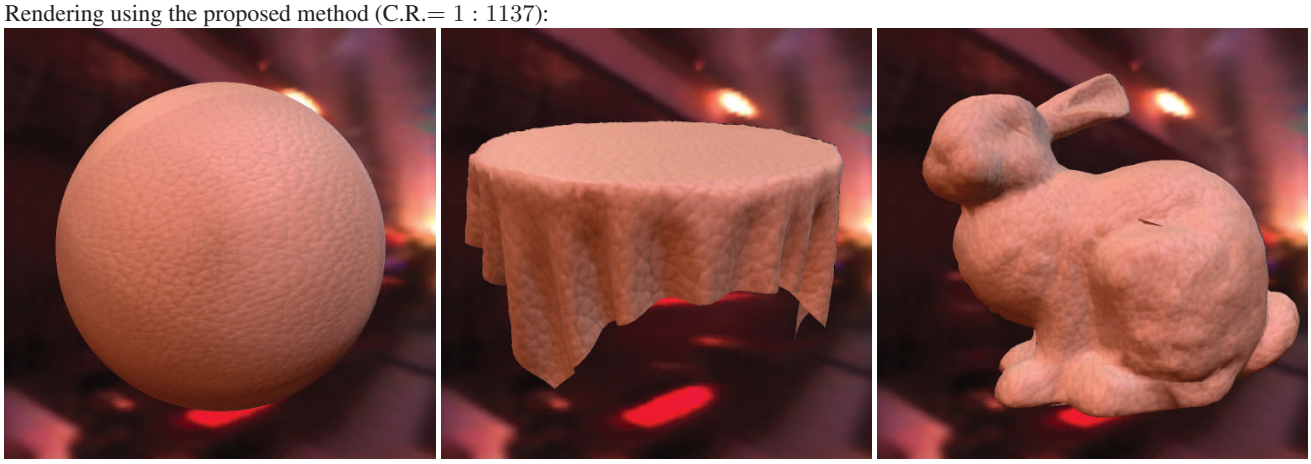


Figure 13: BTF sample **foil02** for **grace** environment.

Rendering using original data:



Rendering using the proposed method (C.R.$= 1 : 1137$):



$\text{MSSIM}_W = 0.9858$	$\text{MSSIM}_W = 0.9850$	$\text{MSSIM}_W = 0.9869$
$\text{MSSIM}_Y = 0.9824$	$\text{MSSIM}_Y = 0.9818$	$\text{MSSIM}_Y = 0.9840$
$\Delta\hat{E}_{LAB} = 1.21$	$\Delta\hat{E}_{LAB} = 1.15$	$\Delta\hat{E}_{LAB} = 1.18$
VDP:	VDP:	VDP:

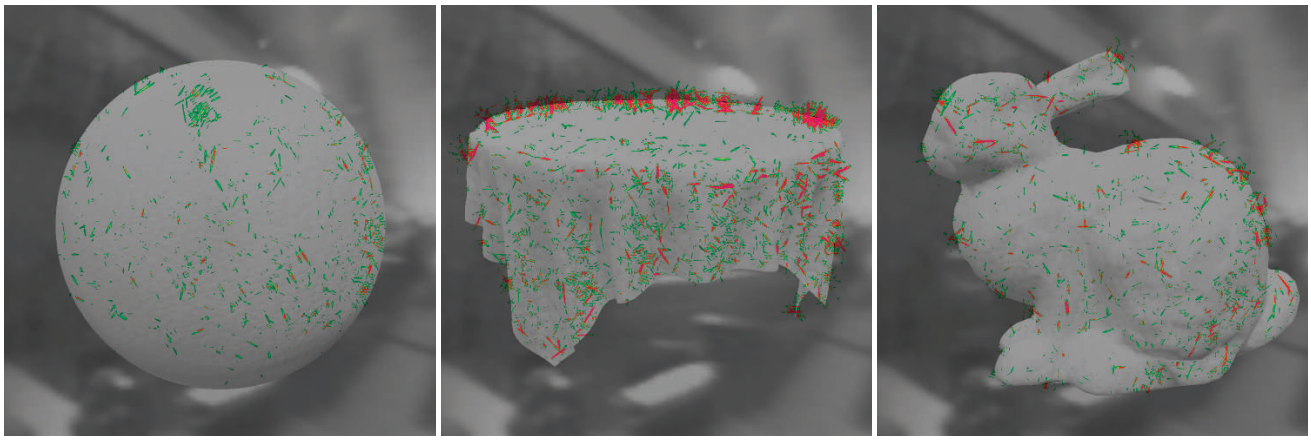
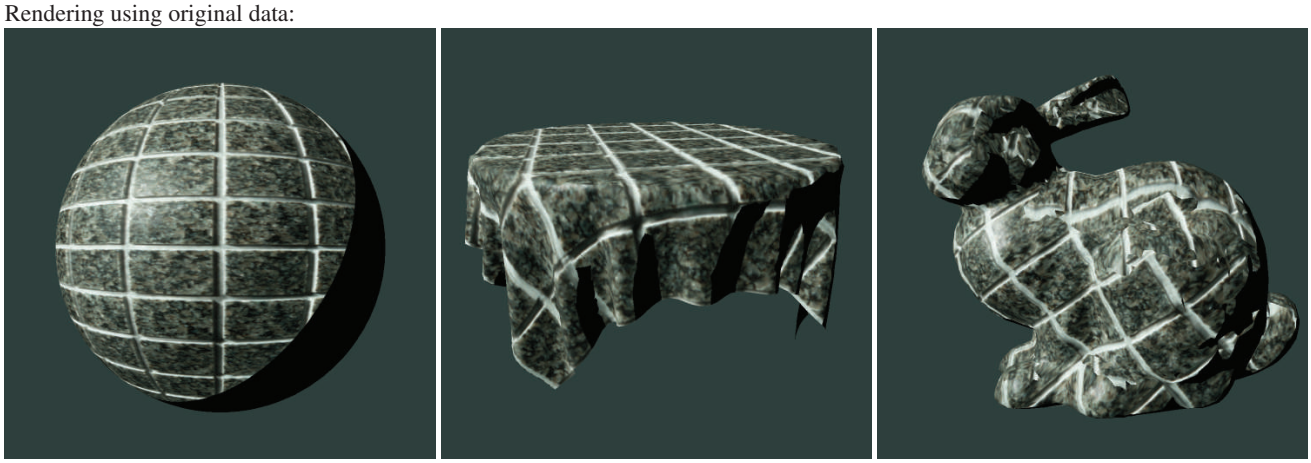
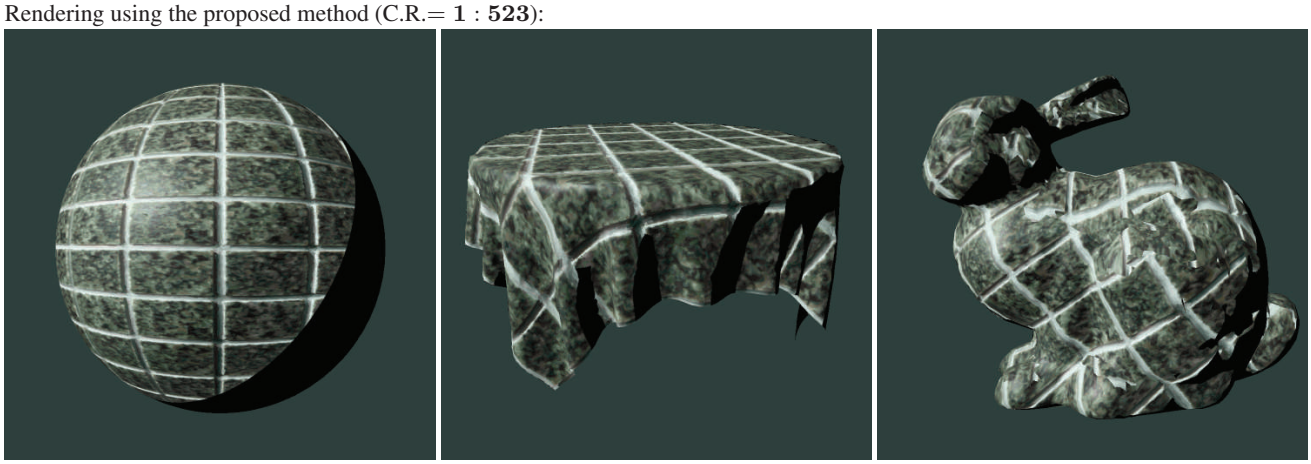


Figure 14: BTF sample **impalla** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{523}$):



MSSIM$_W = 0.9416$	MSSIM$_W = 0.9459$	MSSIM$_W = 0.9440$
MSSIM$_Y = 0.9297$	MSSIM$_Y = 0.9346$	MSSIM$_Y = 0.9326$
$\Delta\hat{E}_{LAB} = 2.00$	$\Delta\hat{E}_{LAB} = 1.78$	$\Delta\hat{E}_{LAB} = 1.95$
VDP:	VDP:	VDP:

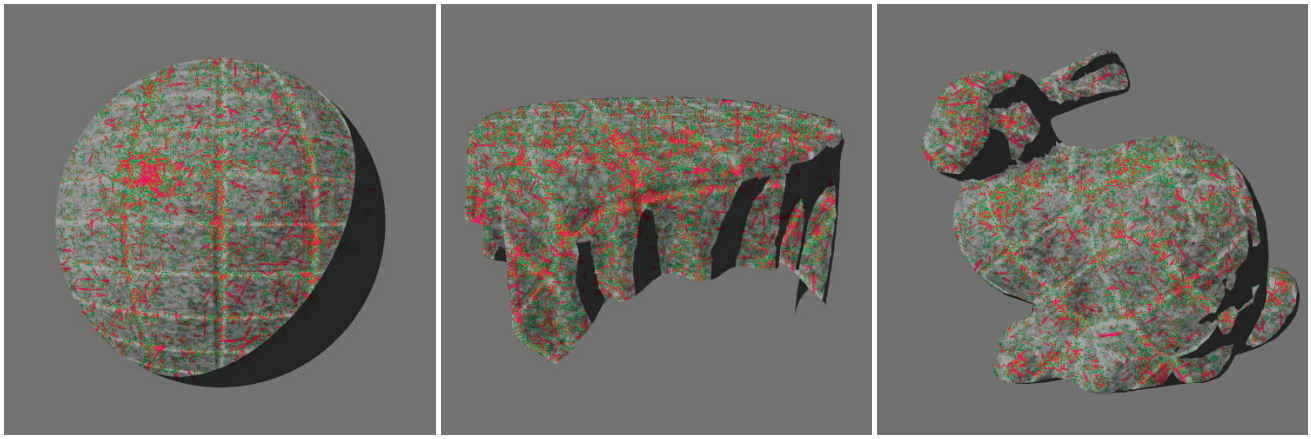


Figure 15: BTF sample **impalla** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{523}$):

$\text{MSSIM}_W = 0.9625$	$\text{MSSIM}_W = 0.9659$	$\text{MSSIM}_W = 0.9639$
$\text{MSSIM}_Y = 0.9551$	$\text{MSSIM}_Y = 0.9589$	$\text{MSSIM}_Y = 0.9569$
$\Delta\hat{E}_{LAB} = 1.82$	$\Delta\hat{E}_{LAB} = 1.65$	$\Delta\hat{E}_{LAB} = 1.82$
VDP:	VDP:	VDP:

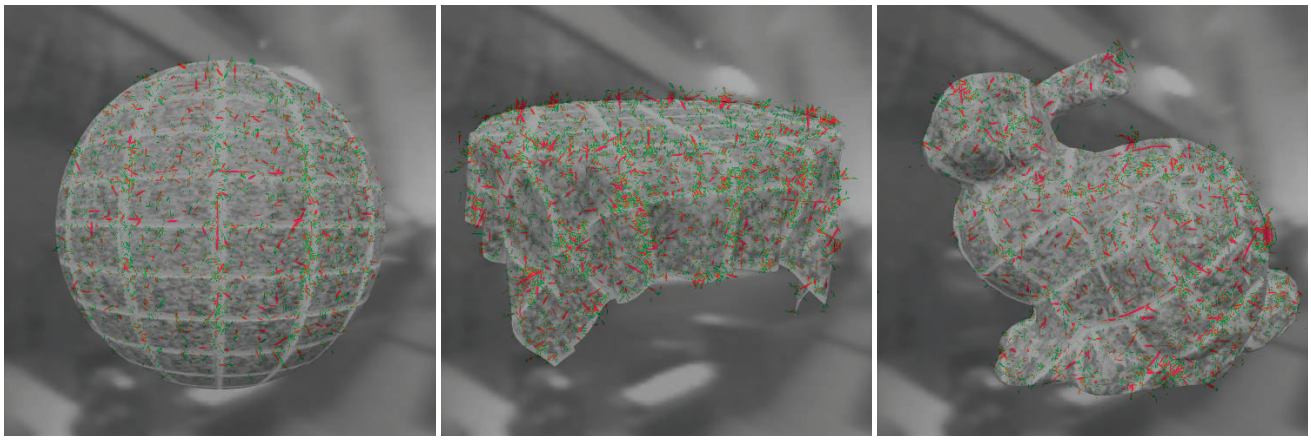
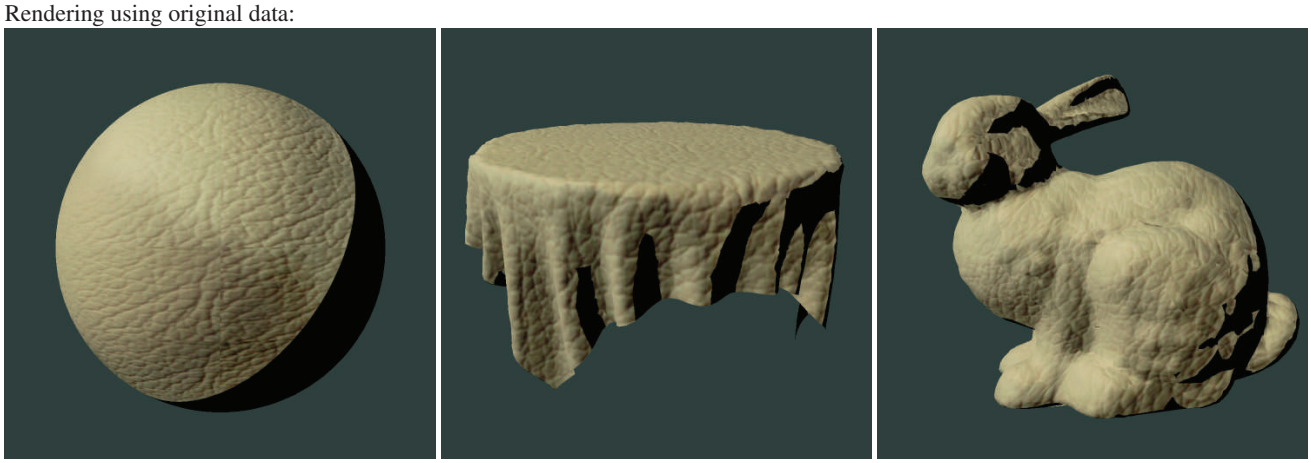
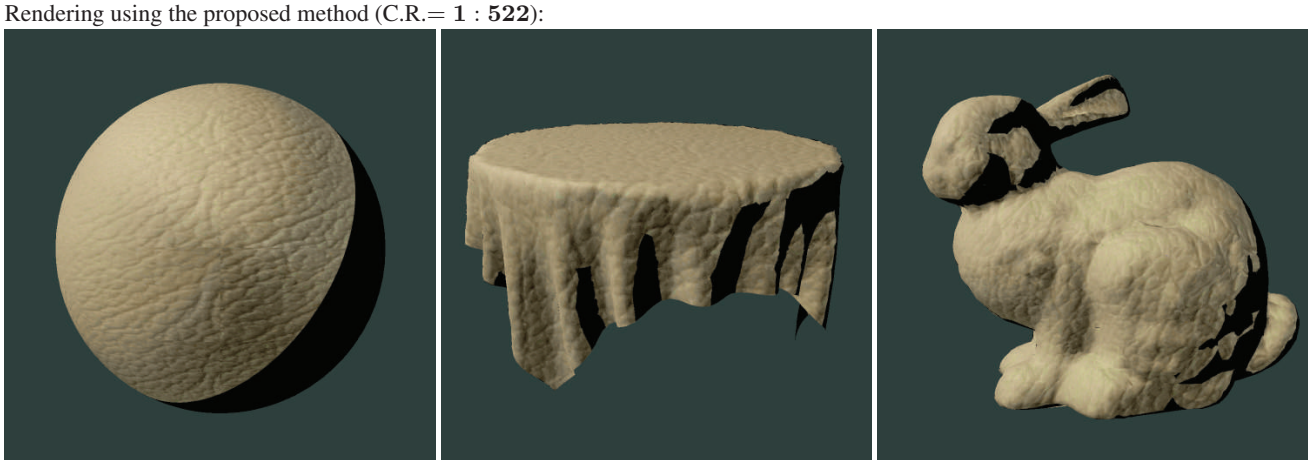


Figure 16: BTF sample **leather02** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{522}$):



$\text{MSSIM}_W = 0.9550$	$\text{MSSIM}_W = 0.9610$	$\text{MSSIM}_W = 0.9625$
$\text{MSSIM}_Y = 0.9444$	$\text{MSSIM}_Y = 0.9517$	$\text{MSSIM}_Y = 0.9538$
$\Delta\hat{E}_{LAB} = 1.56$	$\Delta\hat{E}_{LAB} = 1.39$	$\Delta\hat{E}_{LAB} = 1.46$
VDP:	VDP:	VDP:

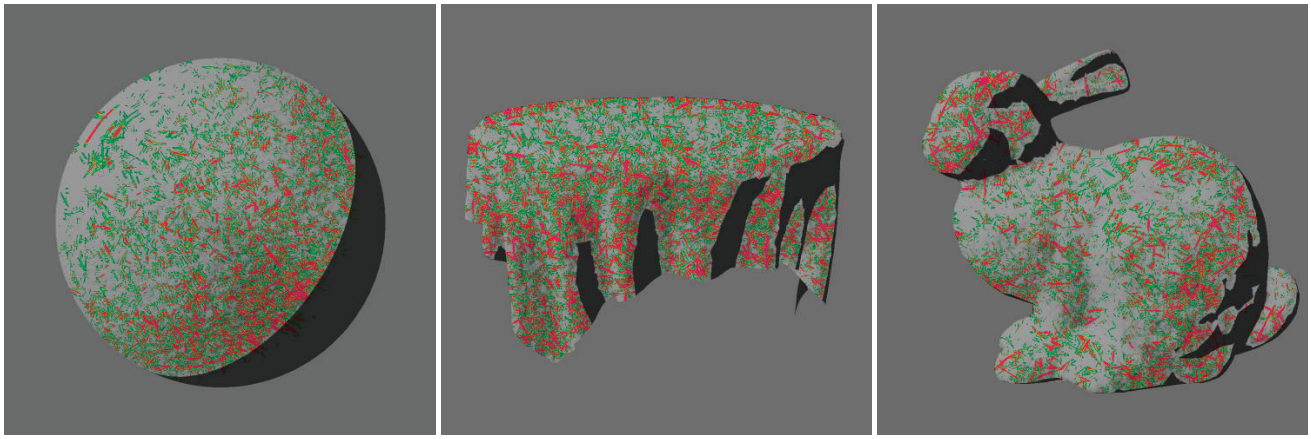
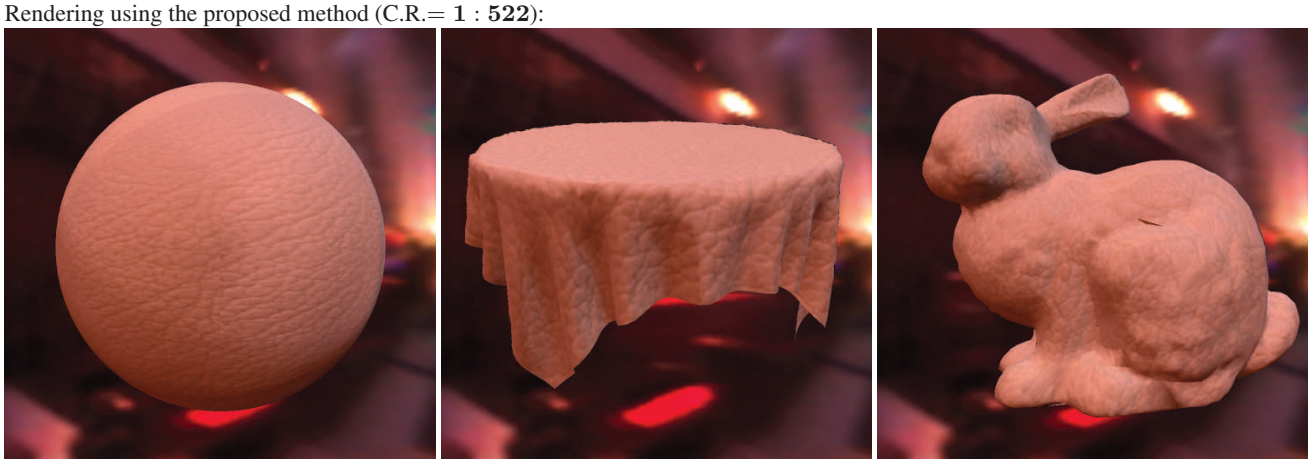


Figure 17: BTF sample **leather02** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1:522}$):



$\text{MSSIM}_W = 0.9834$	$\text{MSSIM}_W = 0.9834$	$\text{MSSIM}_W = 0.9855$
$\text{MSSIM}_Y = 0.9795$	$\text{MSSIM}_Y = 0.9797$	$\text{MSSIM}_Y = 0.9823$
$\Delta\hat{E}_{LAB} = 1.33$	$\Delta\hat{E}_{LAB} = 1.30$	$\Delta\hat{E}_{LAB} = 1.27$
VDP:	VDP:	VDP:

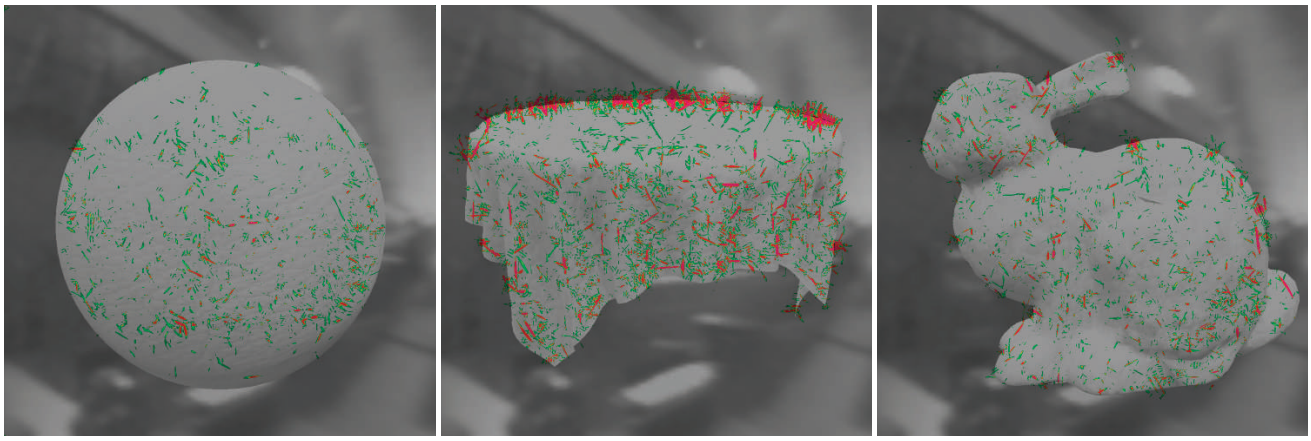
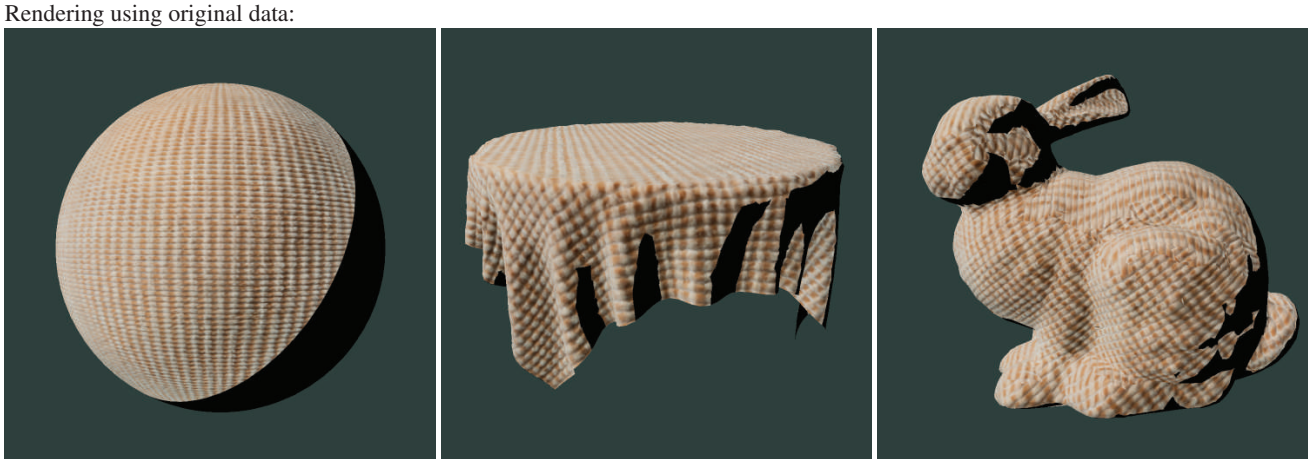
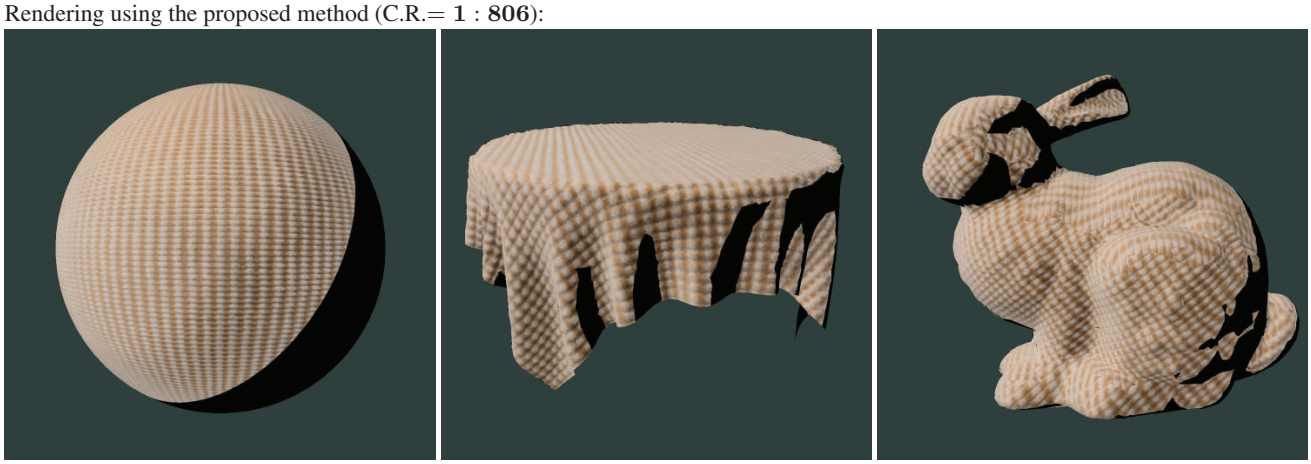


Figure 18: BTF sample **proposte** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{806}$):



MSSIM$_W$ $= 0.9359$	MSSIM$_W$ $= 0.9353$	MSSIM$_W$ $= 0.9400$
MSSIM$_Y$ $= 0.9230$	MSSIM$_Y$ $= 0.9218$	MSSIM$_Y$ $= 0.9278$
$\Delta\hat{E}_{LAB} = 1.74$	$\Delta\hat{E}_{LAB} = 1.60$	$\Delta\hat{E}_{LAB} = 1.73$
VDP:	VDP:	VDP:

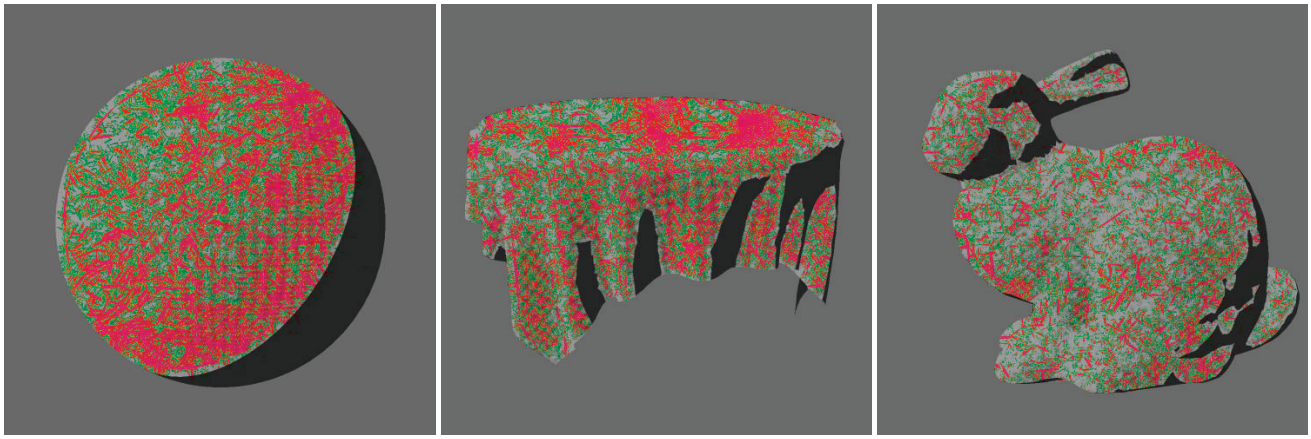
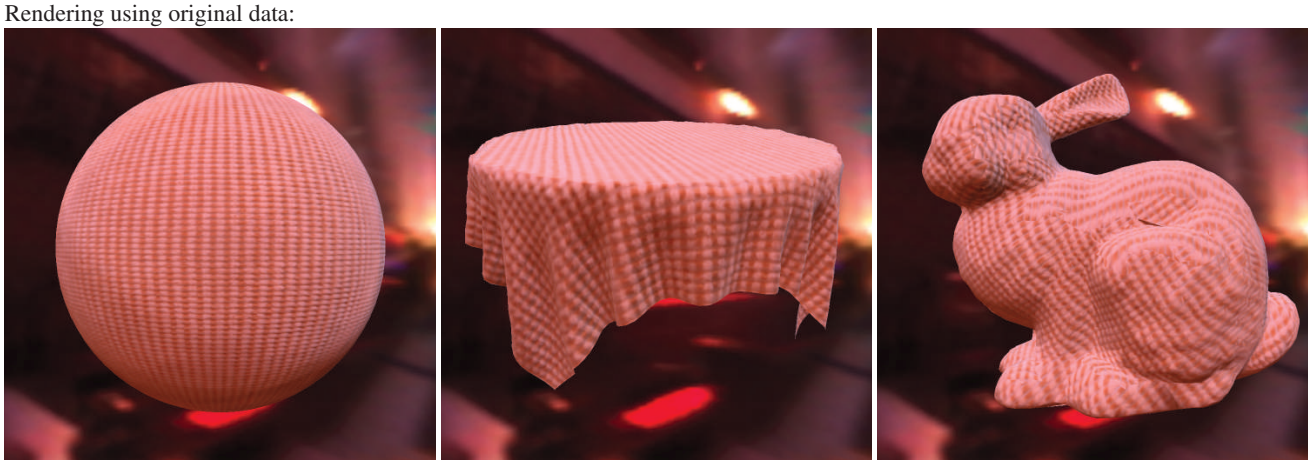
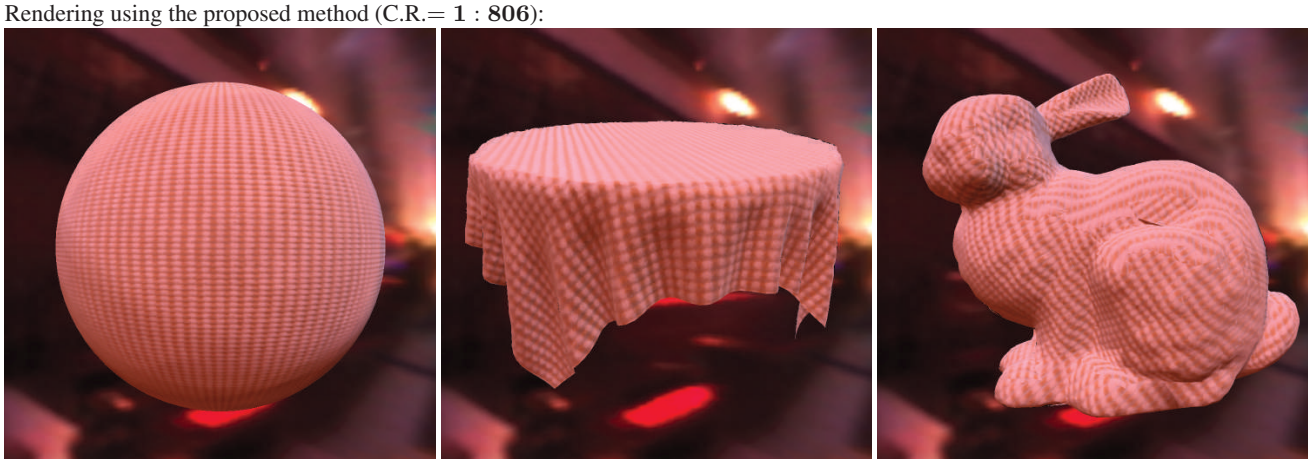


Figure 19: BTF sample **proposte** for **grace** environment.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1:806}$):



$\text{MSSIM}_W = 0.9652$	$\text{MSSIM}_W = 0.9674$	$\text{MSSIM}_W = 0.9658$
$\text{MSSIM}_Y = 0.9580$	$\text{MSSIM}_Y = 0.9606$	$\text{MSSIM}_Y = 0.9591$
$\Delta\hat{E}_{LAB} = 1.56$	$\Delta\hat{E}_{LAB} = 1.46$	$\Delta\hat{E}_{LAB} = 1.58$
VDP:	VDP:	VDP:

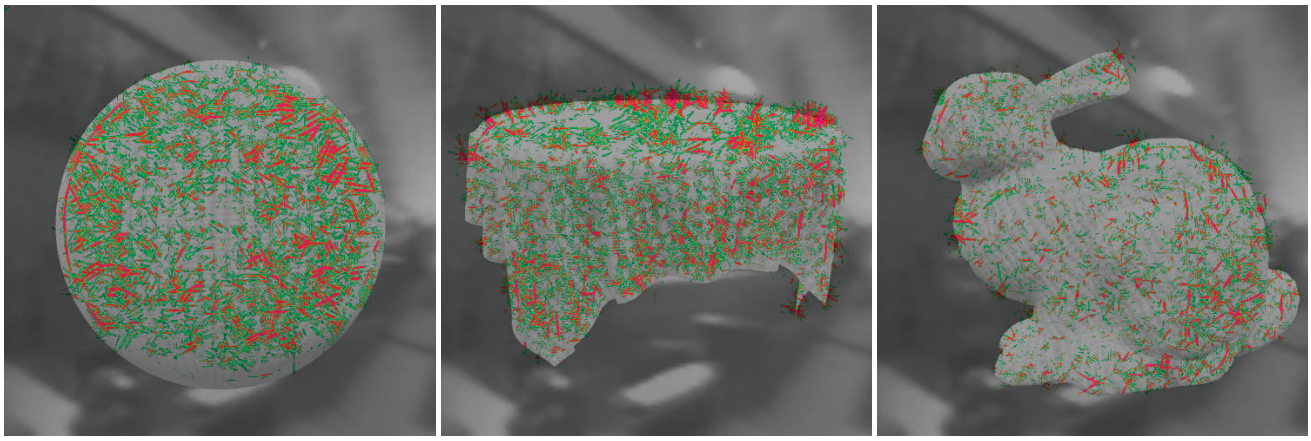


Figure 20: BTF sample **pulli** for point light from the left.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{264}$):

MSSIM$_W = 0.9016$	MSSIM$_W = 0.9245$	MSSIM$_W = 0.9146$
MSSIM$_Y = 0.8785$	MSSIM$_Y = 0.9070$	MSSIM$_Y = 0.8946$
$\Delta\hat{E}_{LAB} = 2.13$	$\Delta\hat{E}_{LAB} = 1.77$	$\Delta\hat{E}_{LAB} = 1.99$
VDP:	VDP:	VDP:

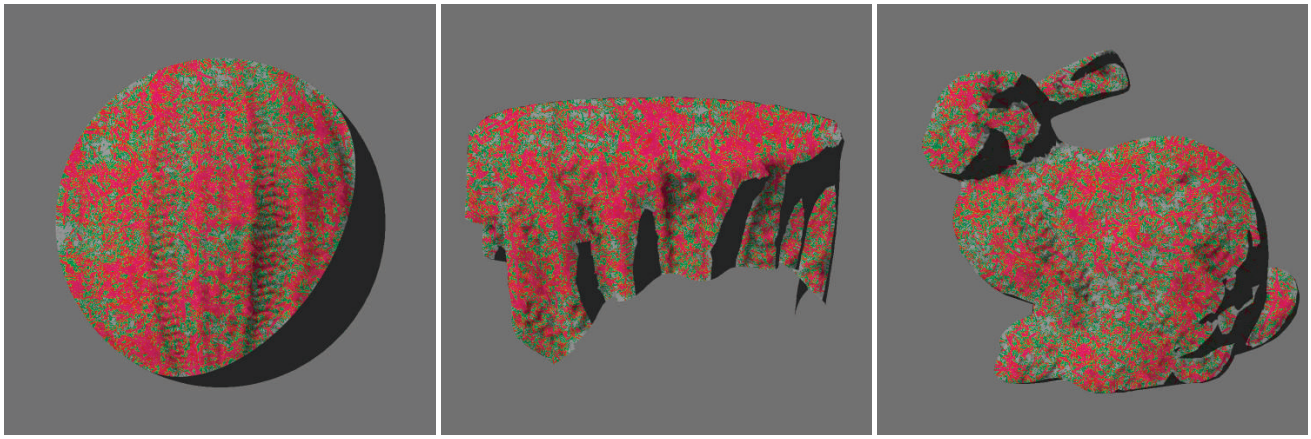


Figure 21: BTF sample **pulli** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.$= \mathbf{1} : \mathbf{264}$):

$\text{MSSIM}_W = 0.9425$	$\text{MSSIM}_W = 0.9570$	$\text{MSSIM}_W = 0.9431$
$\text{MSSIM}_Y = 0.9290$	$\text{MSSIM}_Y = 0.9472$	$\text{MSSIM}_Y = 0.9299$
$\Delta\hat{E}_{LAB} = 1.66$	$\Delta\hat{E}_{LAB} = 1.47$	$\Delta\hat{E}_{LAB} = 1.72$
VDP:	VDP:	VDP:

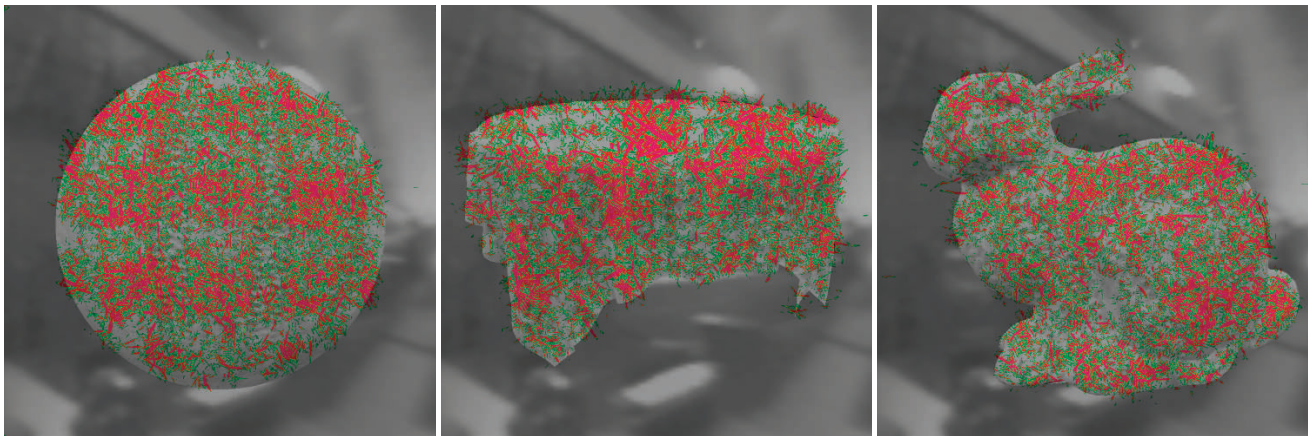
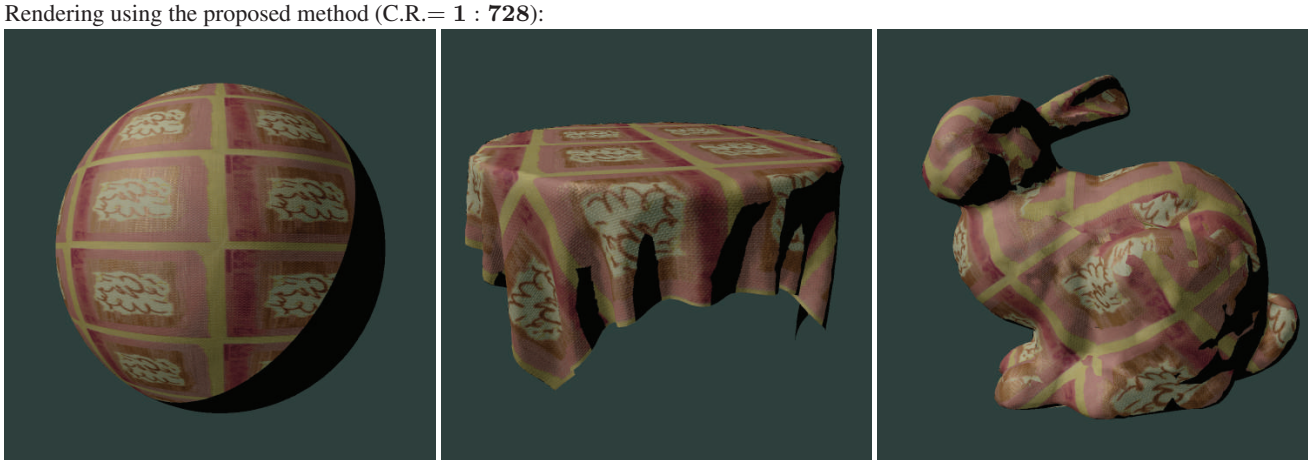


Figure 22: BTF sample **wallpaper** for point light from the left.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{728}$):



$\text{MSSIM}_W = 0.9577$	$\text{MSSIM}_W = 0.9626$	$\text{MSSIM}_W = 0.9607$
$\text{MSSIM}_Y = 0.9493$	$\text{MSSIM}_Y = 0.9552$	$\text{MSSIM}_Y = 0.9530$
$\Delta\hat{E}_{LAB} = 1.44$	$\Delta\hat{E}_{LAB} = 1.28$	$\Delta\hat{E}_{LAB} = 1.41$
VDP:	VDP:	VDP:

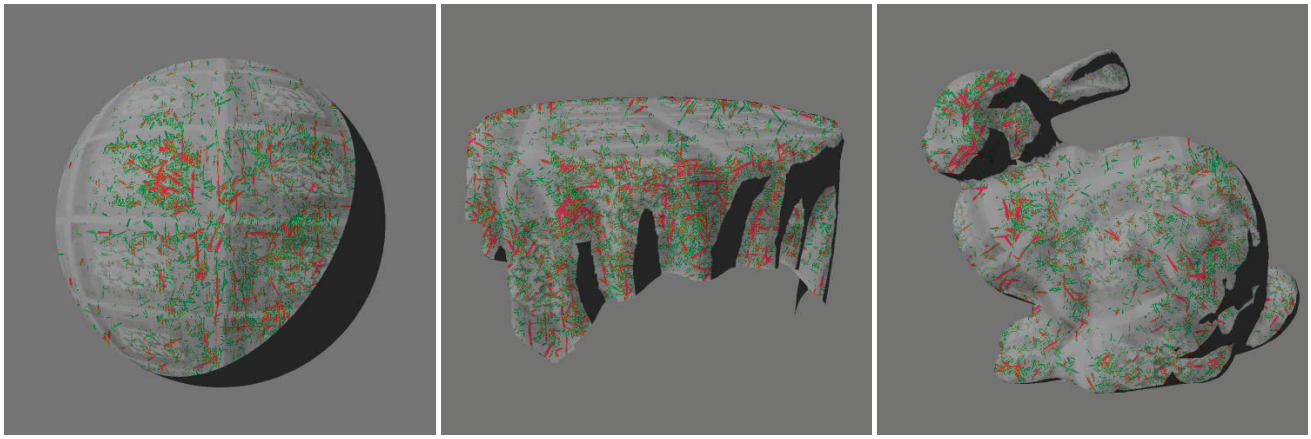


Figure 23: BTF sample **wallpaper** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{728}$):

$\text{MSSIM}_W = 0.9822$	$\text{MSSIM}_W = 0.9808$	$\text{MSSIM}_W = 0.9826$
$\text{MSSIM}_Y = 0.9793$	$\text{MSSIM}_Y = 0.9773$	$\text{MSSIM}_Y = 0.9798$
$\Delta\hat{E}_{LAB} = 1.43$	$\Delta\hat{E}_{LAB} = 1.33$	$\Delta\hat{E}_{LAB} = 1.44$
VDP:	VDP:	VDP:

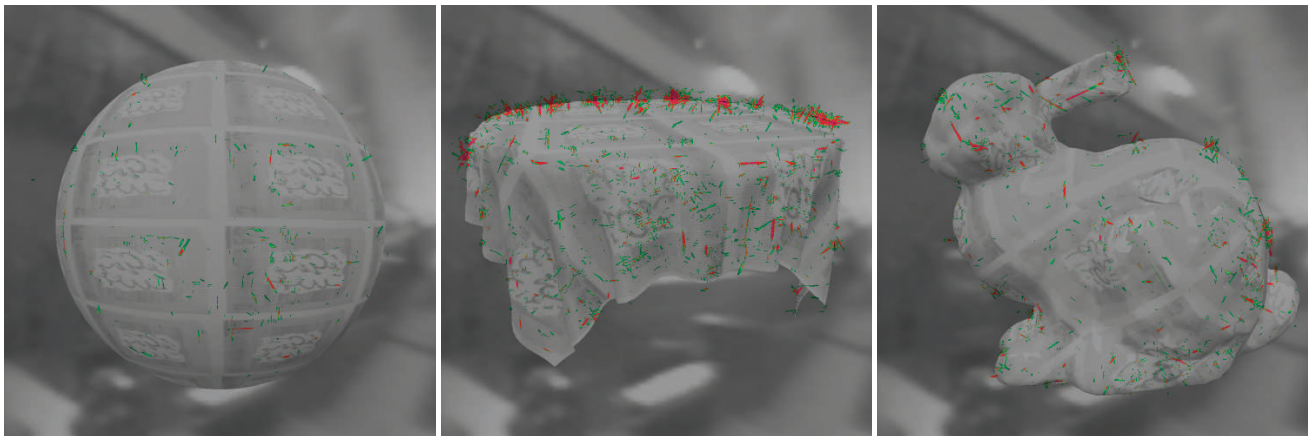
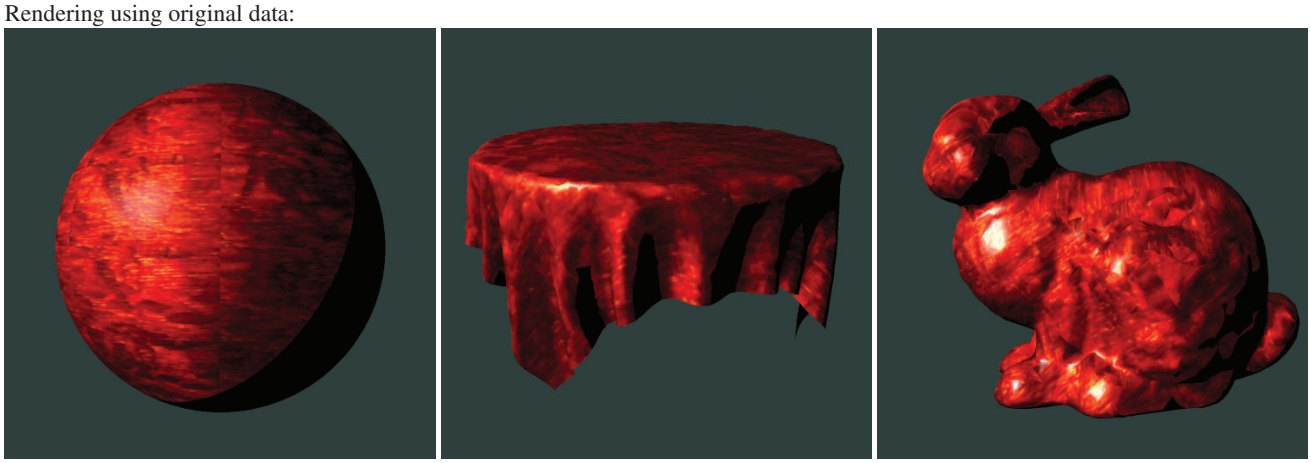
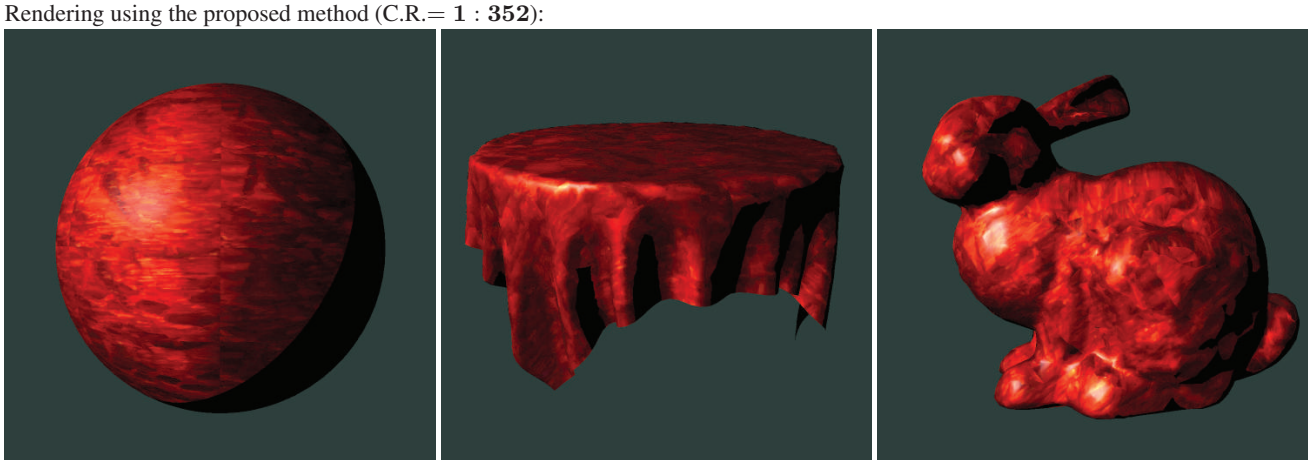


Figure 24: BTF sample **wood01** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{352}$):



$\text{MSSIM}_W = 0.9403$	$\text{MSSIM}_W = 0.9629$	$\text{MSSIM}_W = 0.9461$
$\text{MSSIM}_Y = 0.9323$	$\text{MSSIM}_Y = 0.9580$	$\text{MSSIM}_Y = 0.9392$
$\Delta\hat{E}_{LAB} = 1.99$	$\Delta\hat{E}_{LAB} = 1.70$	$\Delta\hat{E}_{LAB} = 2.12$
VDP:	VDP:	VDP:

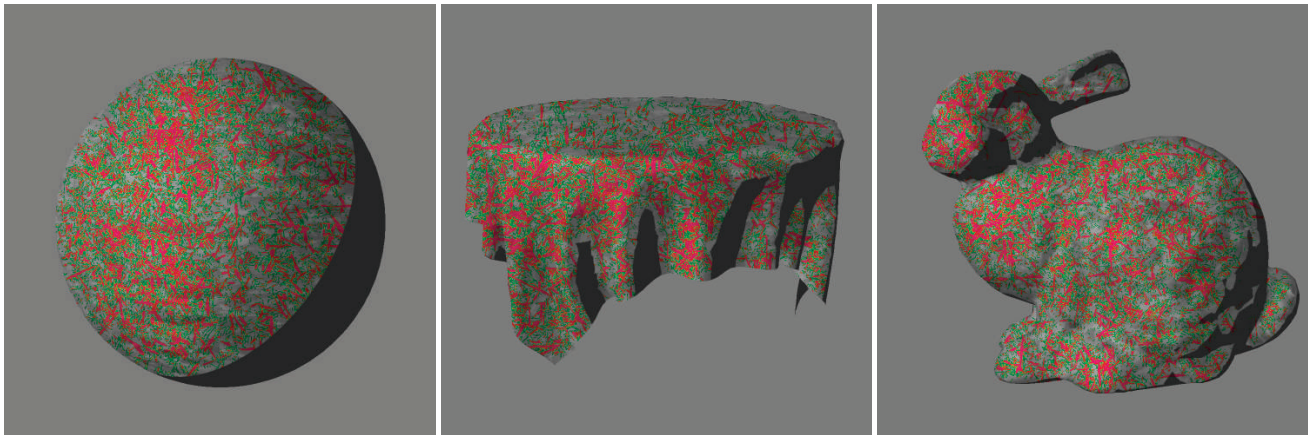
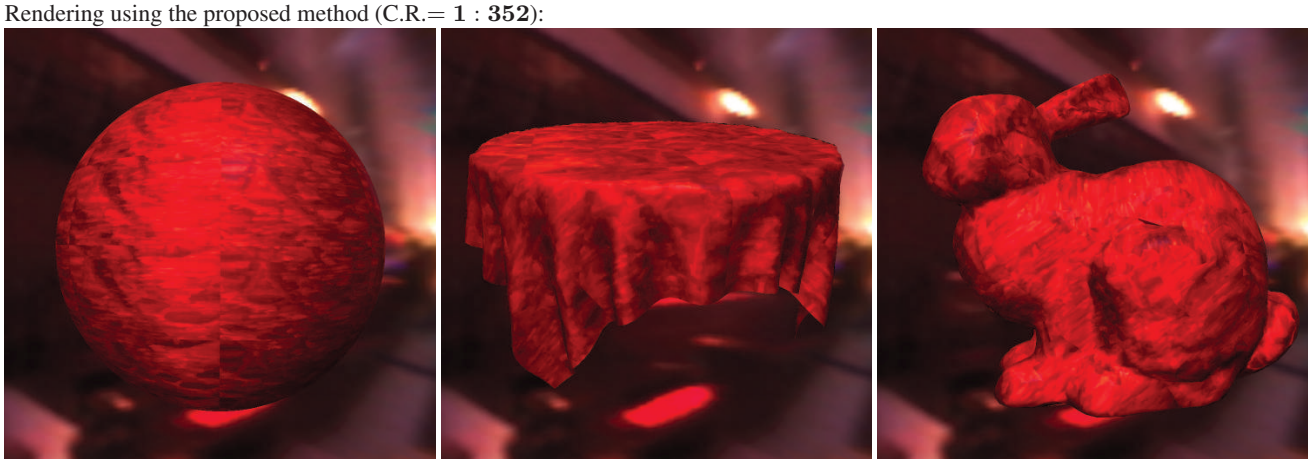


Figure 25: BTF sample **wood01** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 352}$):



$\text{MSSIM}_W = 0.9640$	$\text{MSSIM}_W = 0.9768$	$\text{MSSIM}_W = 0.9631$
$\text{MSSIM}_Y = 0.9592$	$\text{MSSIM}_Y = 0.9741$	$\text{MSSIM}_Y = 0.9582$
$\Delta\hat{E}_{LAB} = 1.75$	$\Delta\hat{E}_{LAB} = 1.53$	$\Delta\hat{E}_{LAB} = 1.75$
VDP:	VDP:	VDP:

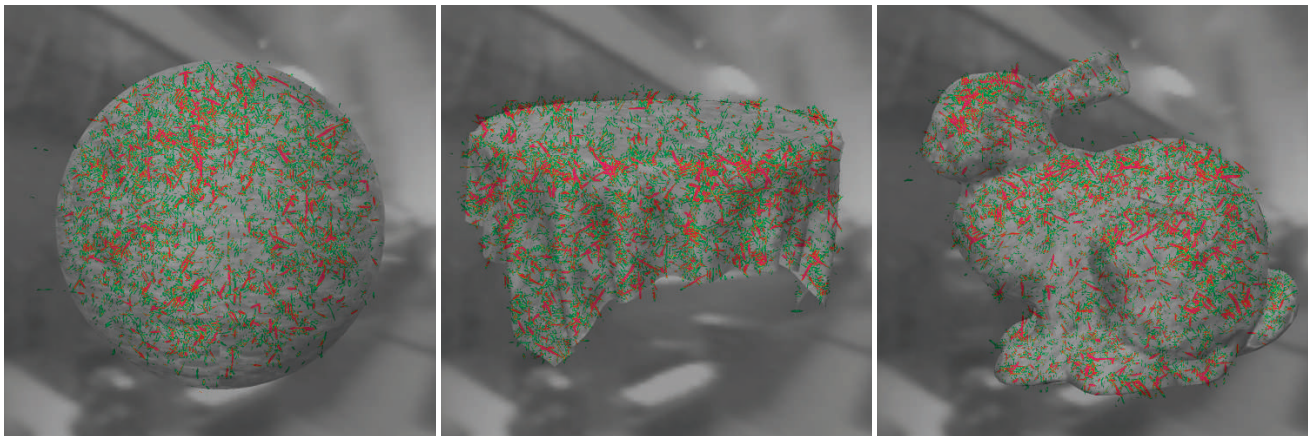
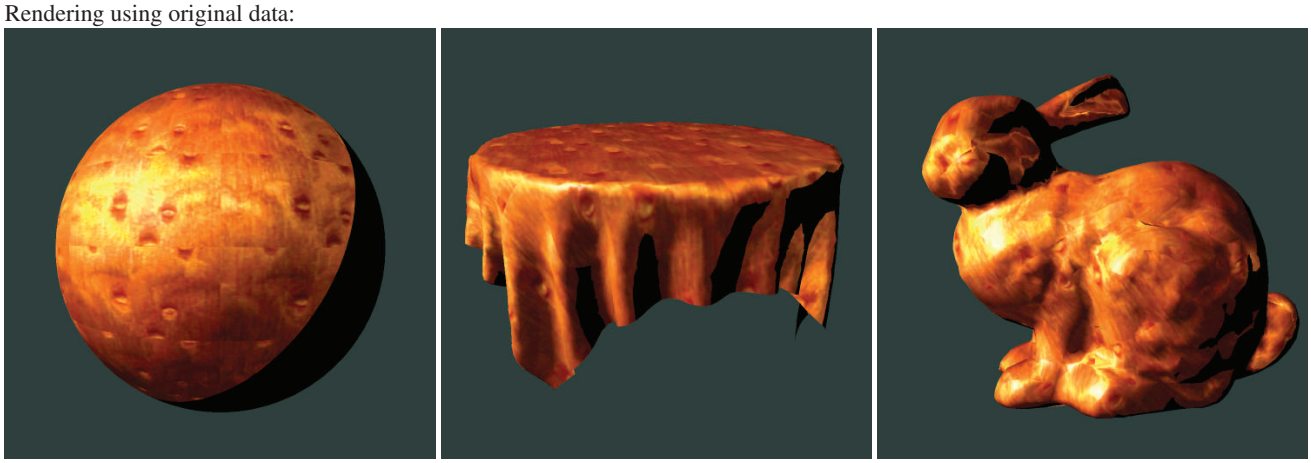
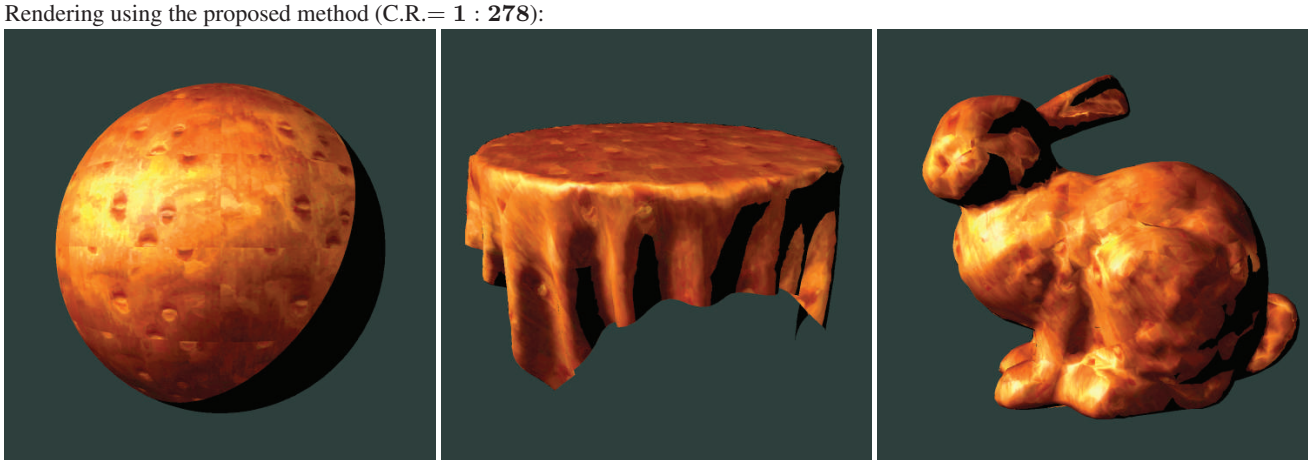


Figure 26: BTF sample **wood02** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1 : 278}$):



$\text{MSSIM}_W = 0.9647$	$\text{MSSIM}_W = 0.9731$	$\text{MSSIM}_W = 0.9715$
$\text{MSSIM}_Y = 0.9601$	$\text{MSSIM}_Y = 0.9692$	$\text{MSSIM}_Y = 0.9683$
$\Delta\hat{E}_{LAB} = 1.65$	$\Delta\hat{E}_{LAB} = 1.46$	$\Delta\hat{E}_{LAB} = 1.68$
VDP:	VDP:	VDP:

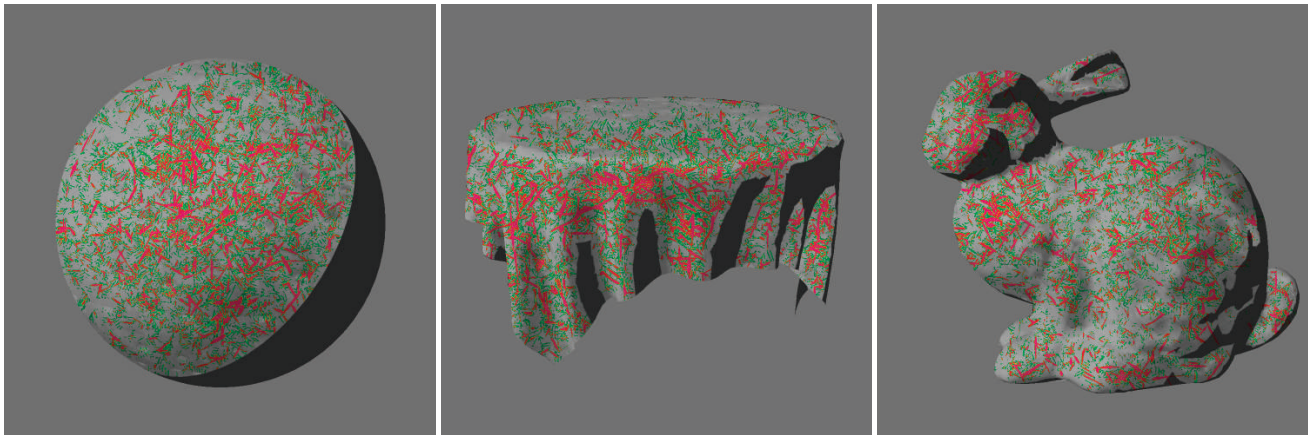
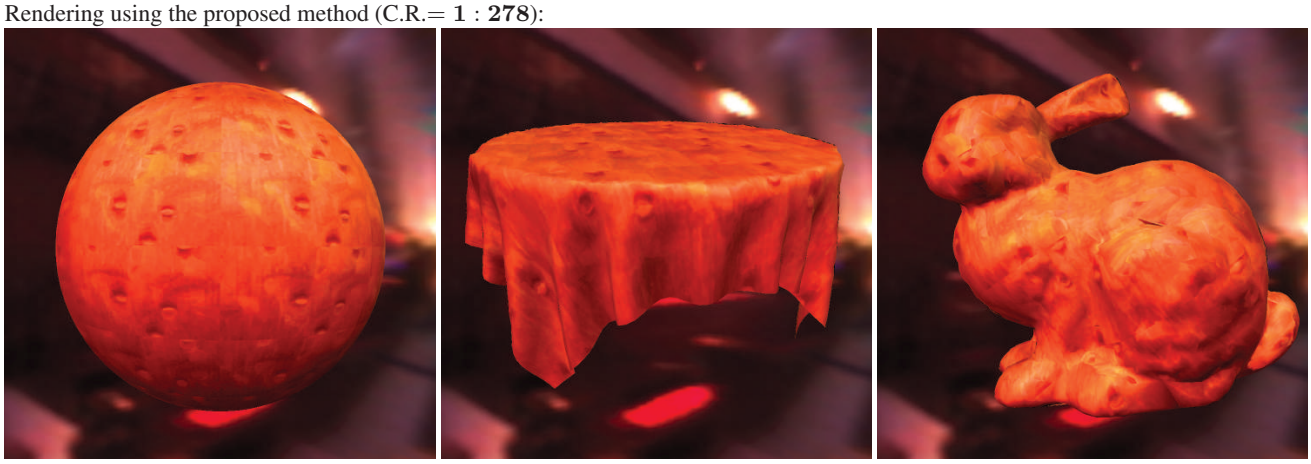


Figure 27: BTF sample **wood02** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 278}$):



$\text{MSSIM}_W = 0.9862$	$\text{MSSIM}_W = 0.9840$	$\text{MSSIM}_W = 0.9850$
$\text{MSSIM}_Y = 0.9851$	$\text{MSSIM}_Y = 0.9819$	$\text{MSSIM}_Y = 0.9837$
$\Delta\hat{E}_{LAB} = 1.35$	$\Delta\hat{E}_{LAB} = 1.25$	$\Delta\hat{E}_{LAB} = 1.40$
VDP:	VDP:	VDP:

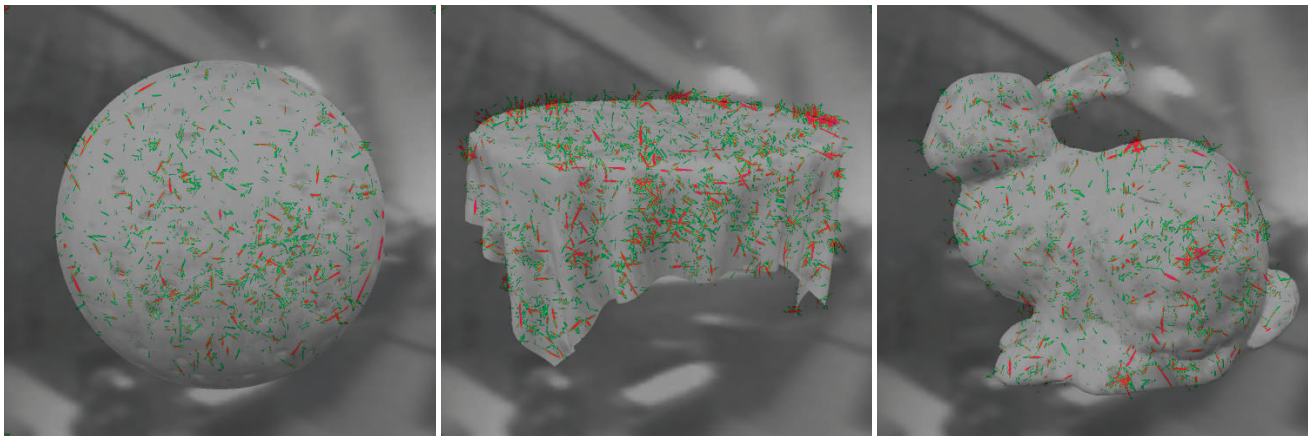
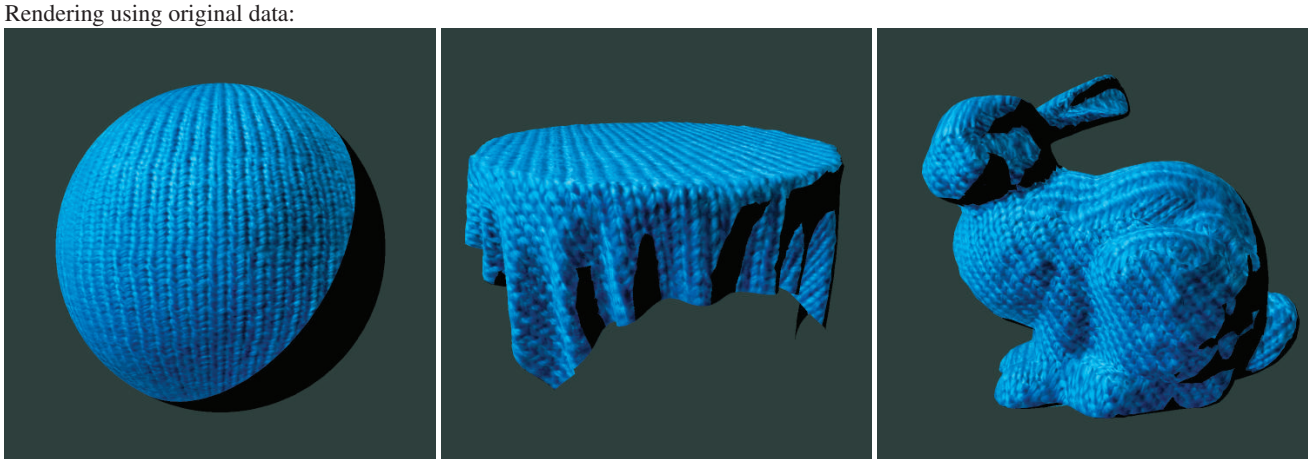
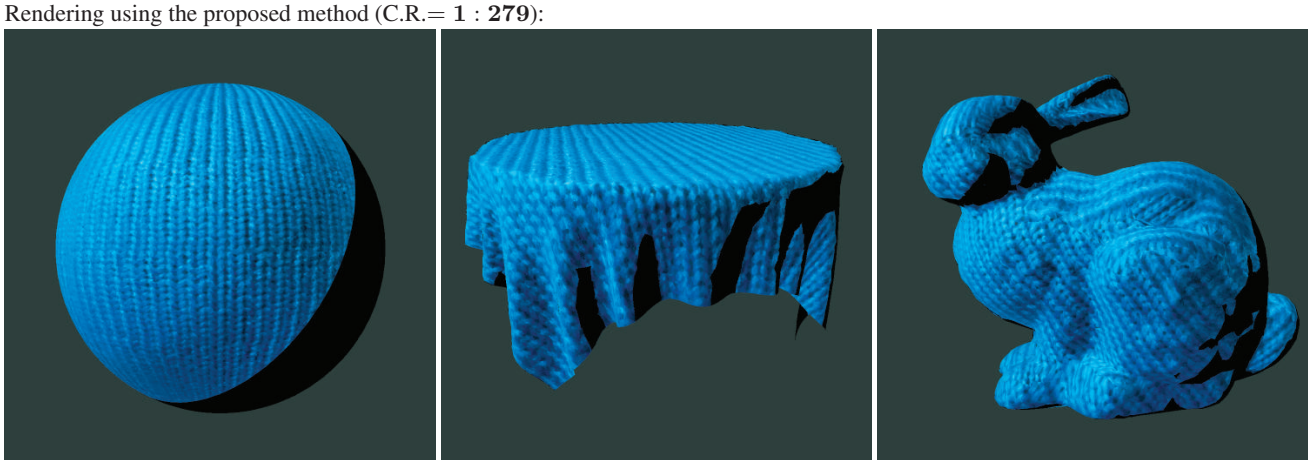


Figure 28: BTF sample **wool** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{279}$):



$\text{MSSIM}_W = 0.8966$	$\text{MSSIM}_W = 0.9159$	$\text{MSSIM}_W = 0.9096$
$\text{MSSIM}_Y = 0.8819$	$\text{MSSIM}_Y = 0.9033$	$\text{MSSIM}_Y = 0.8973$
$\Delta\hat{E}_{LAB} = 2.50$	$\Delta\hat{E}_{LAB} = 2.06$	$\Delta\hat{E}_{LAB} = 2.43$
VDP:	VDP:	VDP:

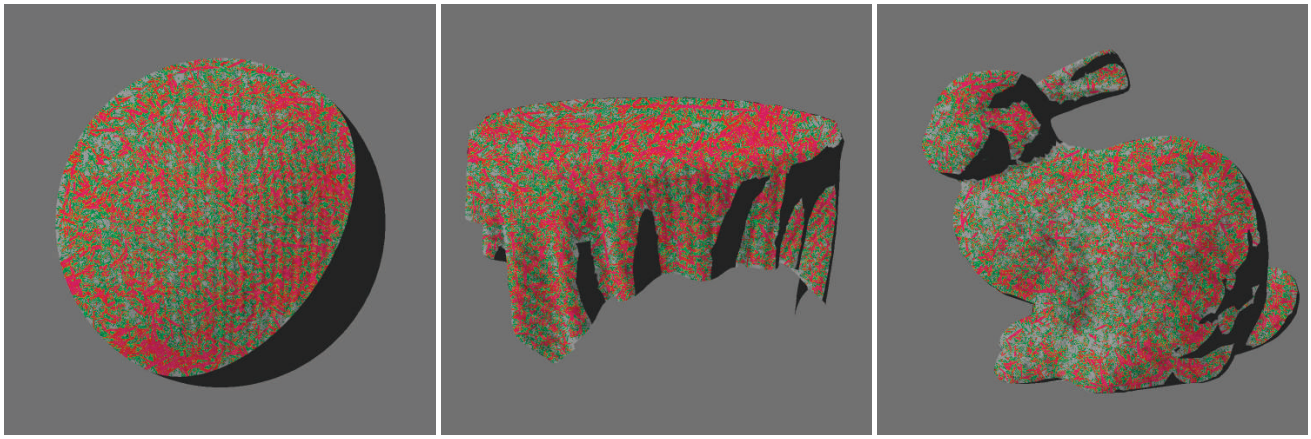
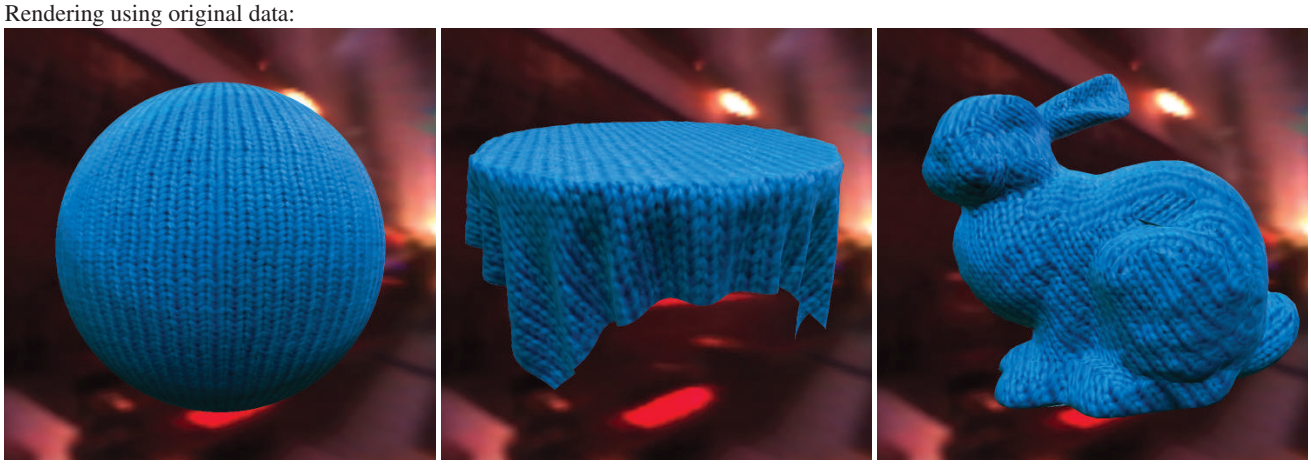
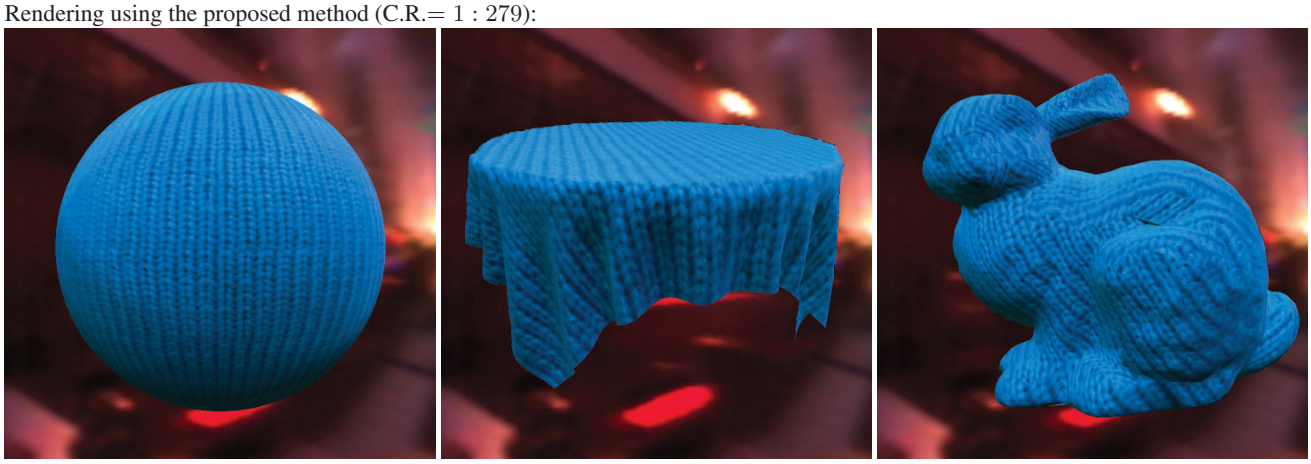


Figure 29: BTF sample **wool** for **grace** environment.

Rendering using original data:



Rendering using the proposed method (C.R.$= 1 : 279$):



$\text{MSSIM}_W = 0.9384$	$\text{MSSIM}_W = 0.9507$	$\text{MSSIM}_W = 0.9401$
$\text{MSSIM}_Y = 0.9294$	$\text{MSSIM}_Y = 0.9429$	$\text{MSSIM}_Y = 0.9318$
$\Delta\hat{E}_{LAB} = 1.91$	$\Delta\hat{E}_{LAB} = 1.69$	$\Delta\hat{E}_{LAB} = 2.01$
VDP:	VDP:	VDP:

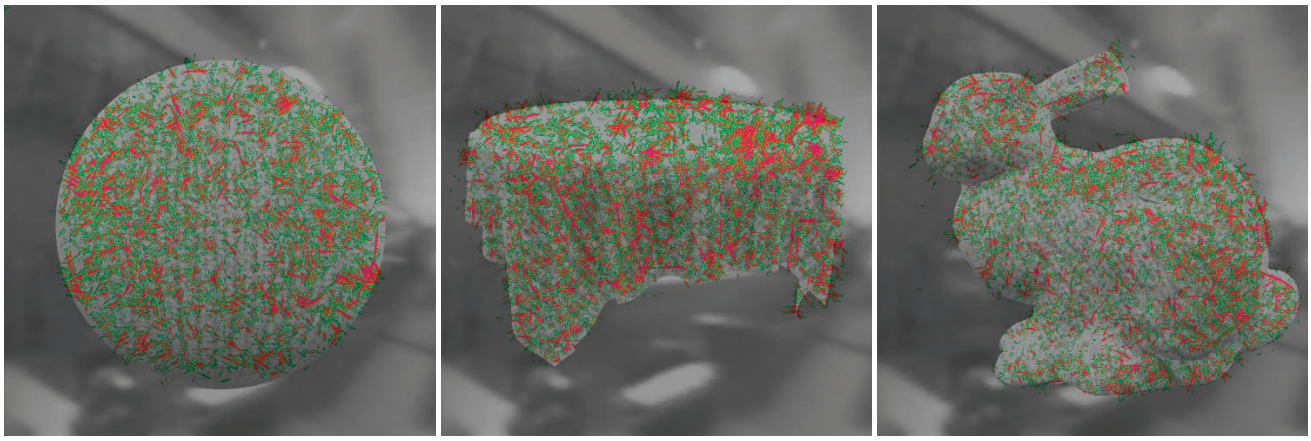
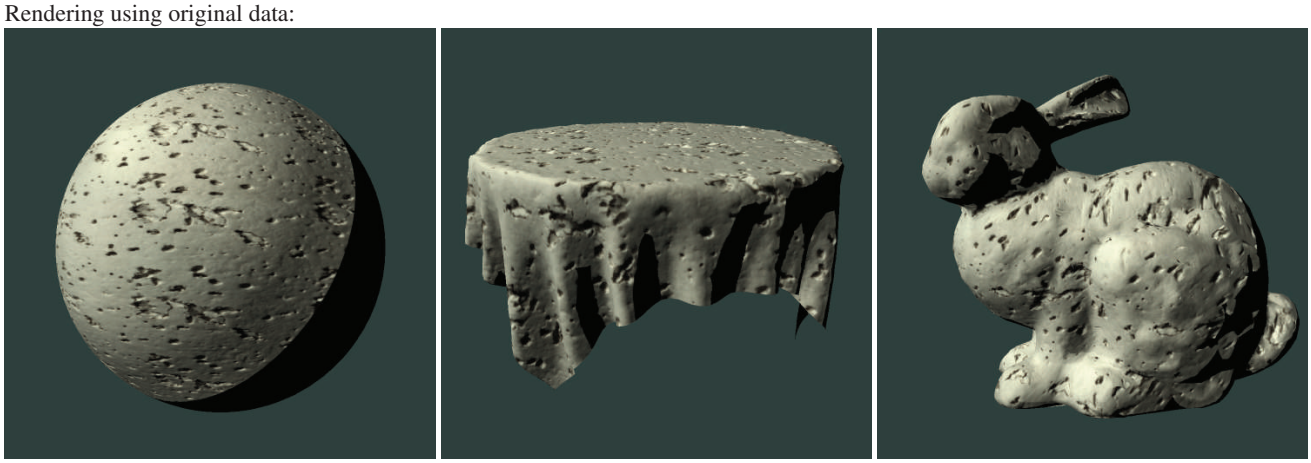
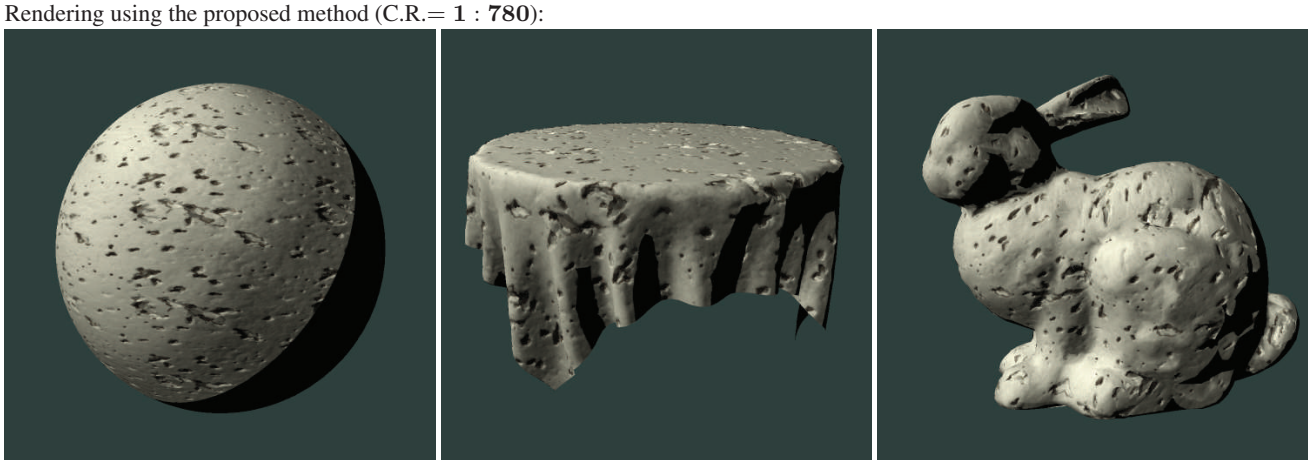


Figure 30: BTF sample **ceilingHDR** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{780}$):



MSSIM$_W$ $= 0.9569$	MSSIM$_W$ $= 0.9582$	MSSIM$_W$ $= 0.9573$
MSSIM$_Y$ $= 0.9463$	MSSIM$_Y$ $= 0.9479$	MSSIM$_Y$ $= 0.9468$
$\Delta\hat{E}_{LAB} = 1.43$	$\Delta\hat{E}_{LAB} = 1.26$	$\Delta\hat{E}_{LAB} = 1.49$
VDP:	VDP:	VDP:

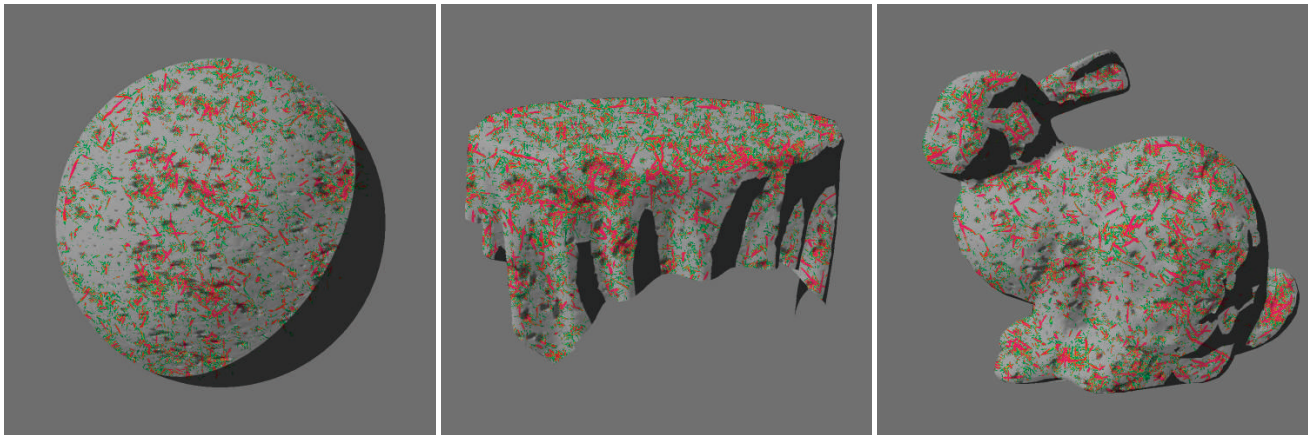


Figure 31: BTF sample **ceilingHDR** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{780}$):

$\text{MSSIM}_W = 0.9761$	$\text{MSSIM}_W = 0.9745$	$\text{MSSIM}_W = 0.9736$
$\text{MSSIM}_Y = 0.9708$	$\text{MSSIM}_Y = 0.9689$	$\text{MSSIM}_Y = 0.9679$
$\Delta\hat{E}_{LAB} = 1.43$	$\Delta\hat{E}_{LAB} = 1.30$	$\Delta\hat{E}_{LAB} = 1.49$
VDP:	VDP:	VDP:

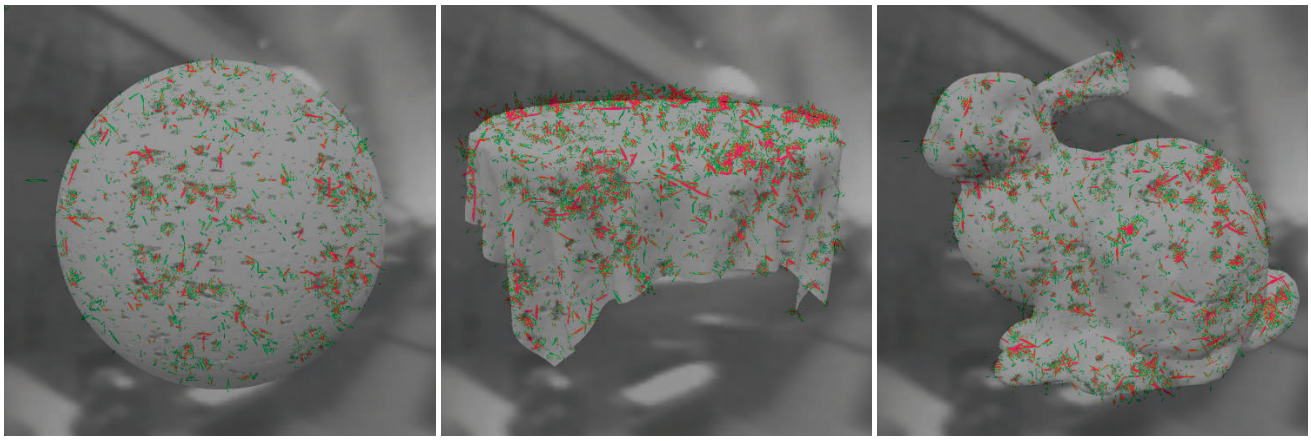
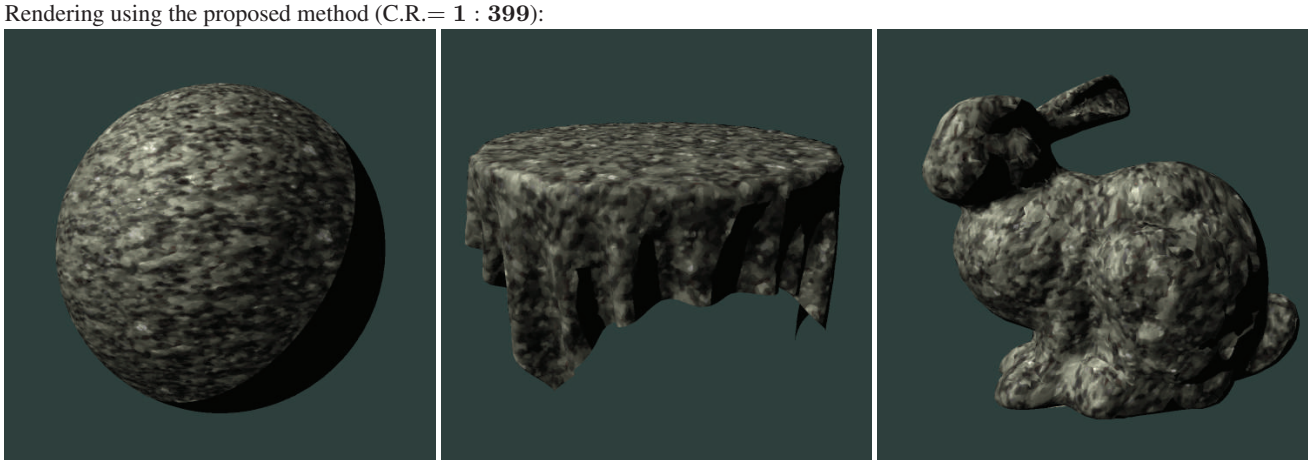


Figure 32: BTF sample **floortileHDR** for point light from the left.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{399}$):



MSSIM$_W$ $= 0.9444$	MSSIM$_W$ $= 0.9594$	MSSIM$_W$ $= 0.9492$
MSSIM$_Y$ $= 0.9306$	MSSIM$_Y$ $= 0.9493$	MSSIM$_Y$ $= 0.9367$
$\Delta\hat{E}_{LAB} = 1.44$	$\Delta\hat{E}_{LAB} = 1.155$	$\Delta\hat{E}_{LAB} = 1.41$
VDP:	VDP:	VDP:

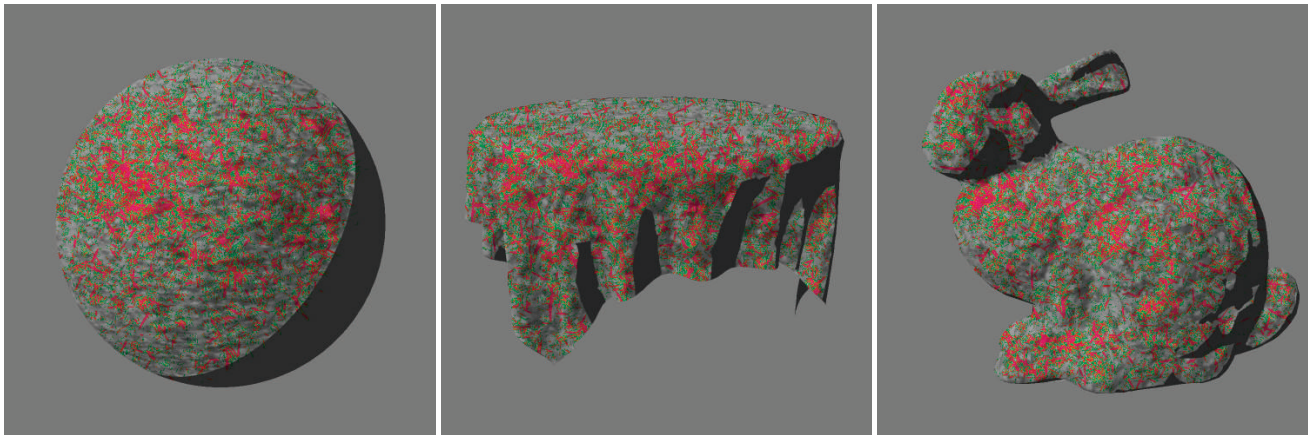


Figure 33: BTF sample **floortileHDR** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1 : 399}$):

$\text{MSSIM}_W = 0.9583$	$\text{MSSIM}_W = 0.9650$	$\text{MSSIM}_W = 0.9590$
$\text{MSSIM}_Y = 0.9486$	$\text{MSSIM}_Y = 0.9567$	$\text{MSSIM}_Y = 0.9492$
$\Delta\hat{E}_{LAB} = 1.61$	$\Delta\hat{E}_{LAB} = 1.43$	$\Delta\hat{E}_{LAB} = 1.64$
VDP:	VDP:	VDP:

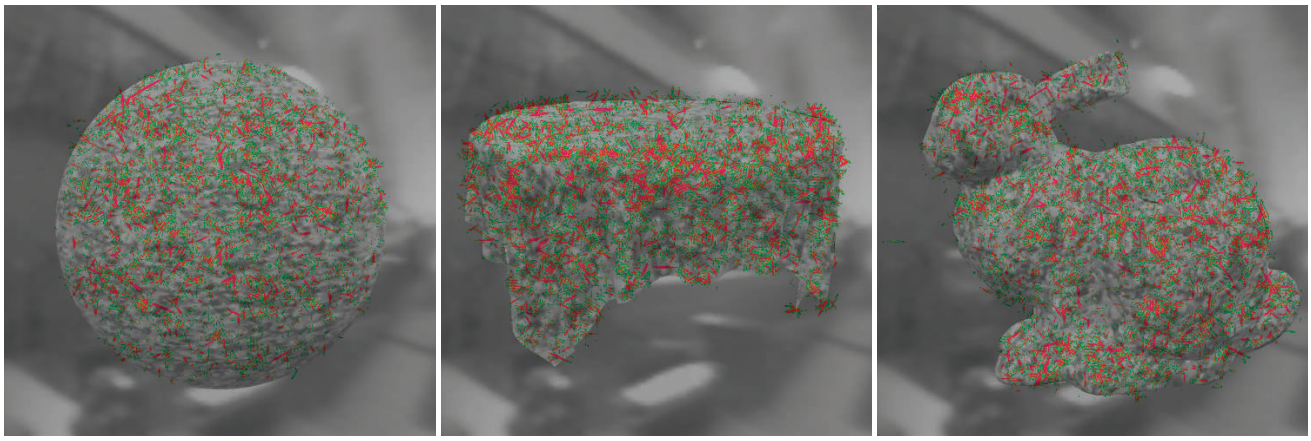
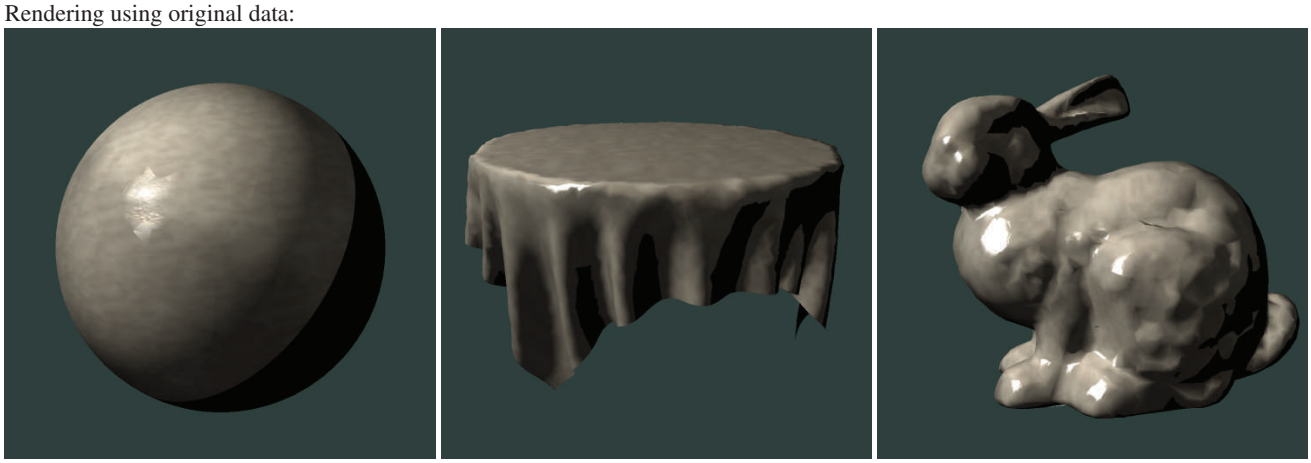
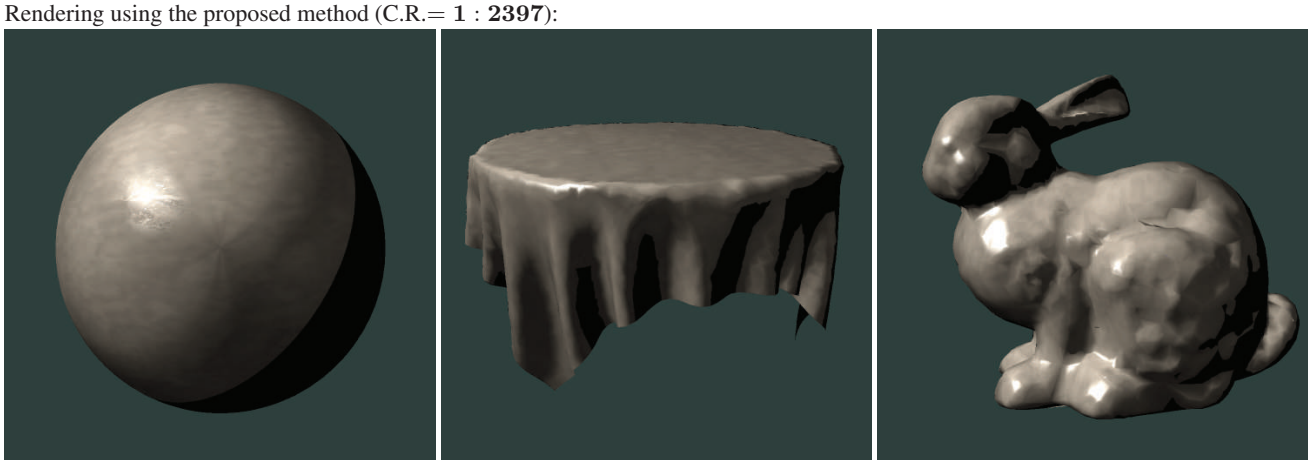


Figure 34: BTF sample **pinktileHDR** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{2397}$):



$\text{MSSIM}_W = 0.9910$	$\text{MSSIM}_W = 0.9923$	$\text{MSSIM}_W = 0.9899$
$\text{MSSIM}_Y = 0.9888$	$\text{MSSIM}_Y = 0.9904$	$\text{MSSIM}_Y = 0.9874$
$\Delta\hat{E}_{LAB} = 0.81$	$\Delta\hat{E}_{LAB} = 0.65$	$\Delta\hat{E}_{LAB} = 0.83$
VDP:	VDP:	VDP:

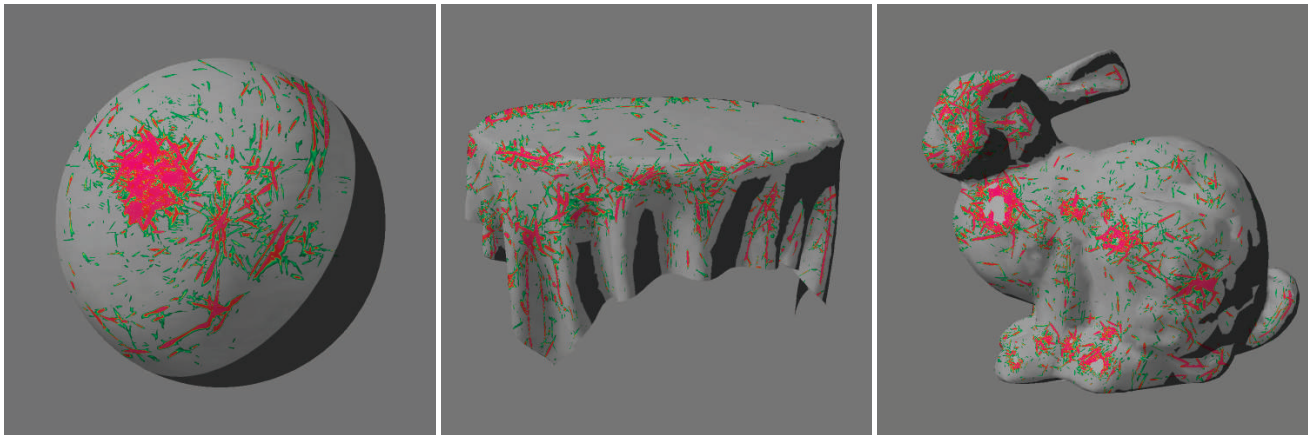
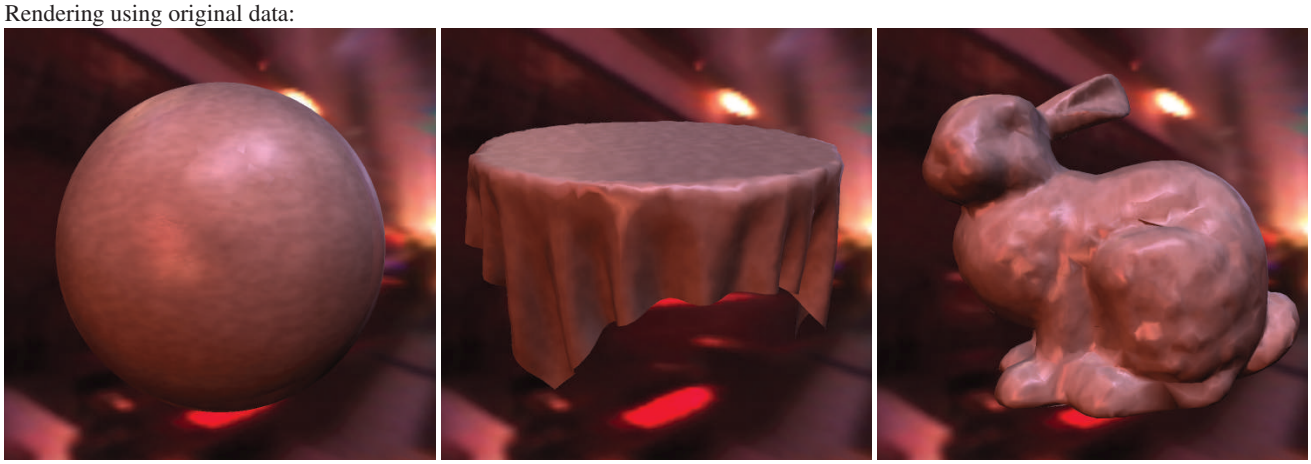
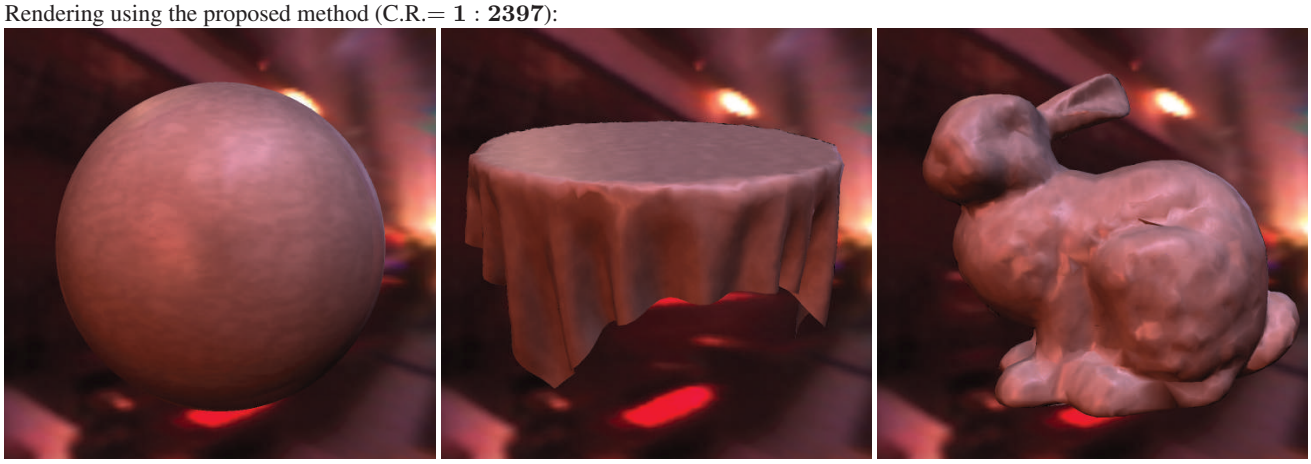


Figure 35: BTF sample **pinktileHDR** for **grace** environment.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{2397}$):



$\text{MSSIM}_W = 0.9973$	$\text{MSSIM}_W = 0.9942$	$\text{MSSIM}_W = 0.9921$
$\text{MSSIM}_Y = 0.9967$	$\text{MSSIM}_Y = 0.9929$	$\text{MSSIM}_Y = 0.9903$
$\Delta\hat{E}_{LAB} = 1.01$	$\Delta\hat{E}_{LAB} = 0.88$	$\Delta\hat{E}_{LAB} = 1.06$
VDP:	VDP:	VDP:

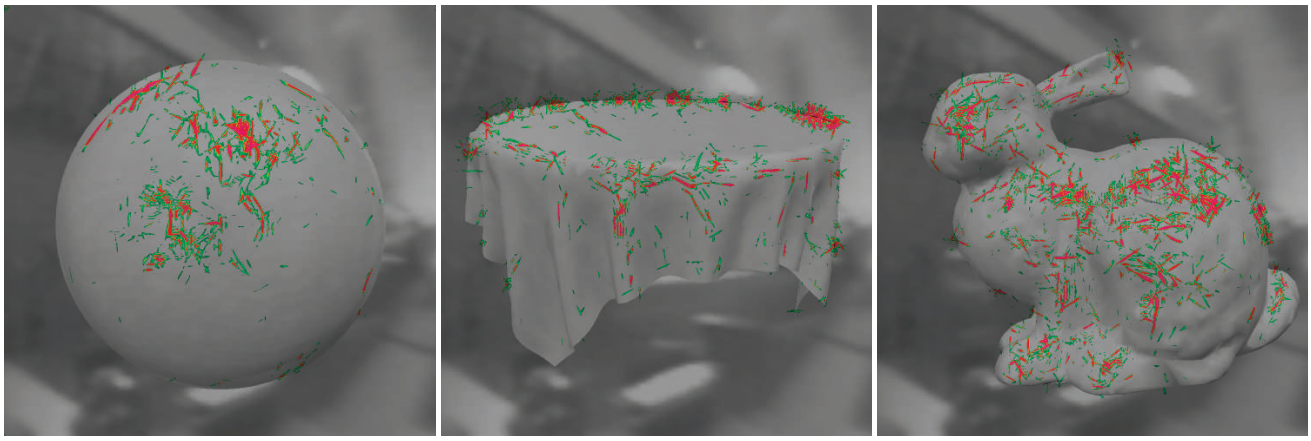
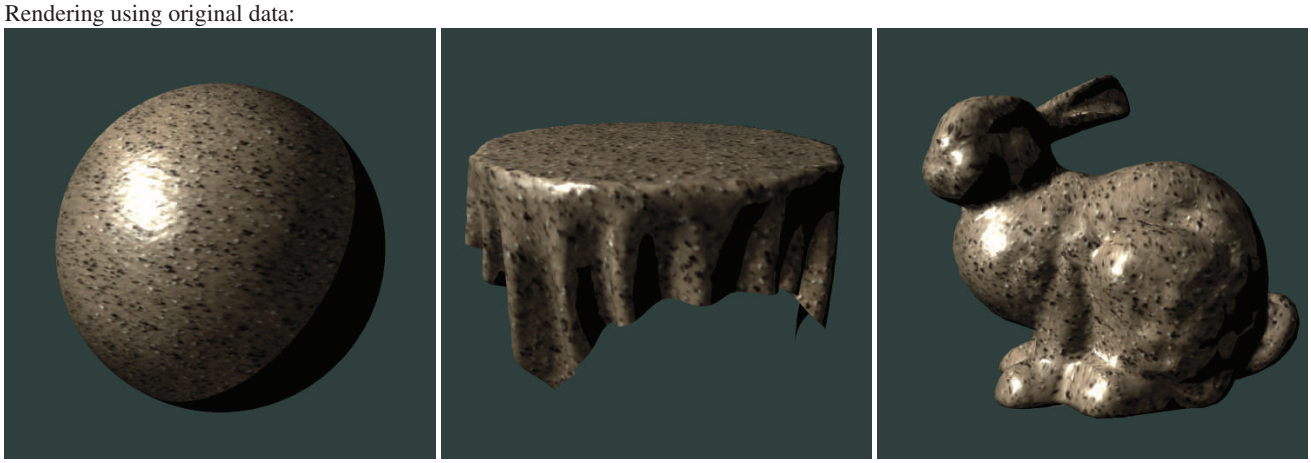
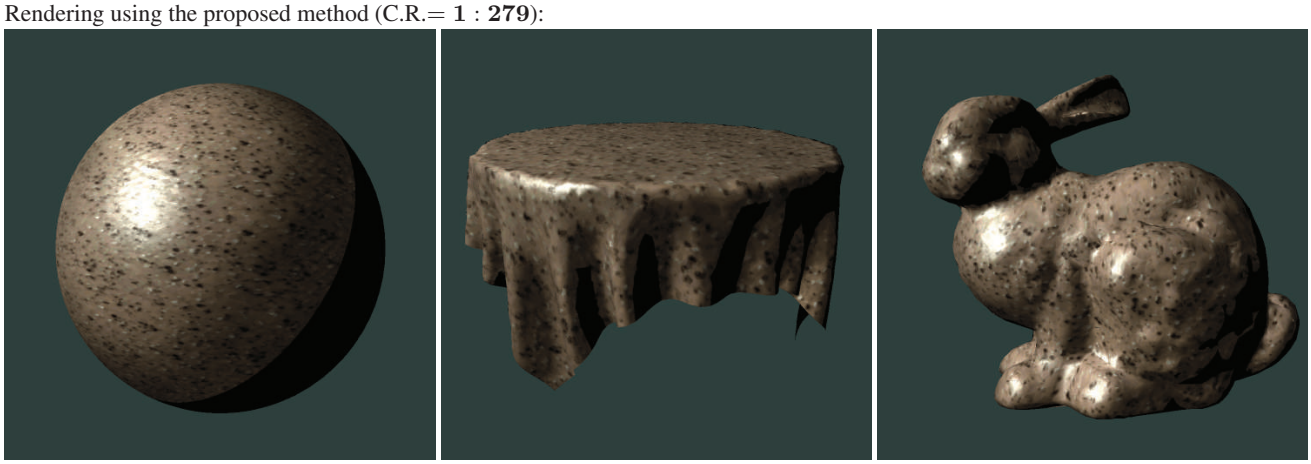


Figure 36: BTF sample **walkwayHDR** for point light from the left.

Rendering using original data:



Rendering using the proposed method (C.R.= $\mathbf{1}$: $\mathbf{279}$):



$\text{MSSIM}_W = 0.9579$	$\text{MSSIM}_W = 0.9705$	$\text{MSSIM}_W = 0.9613$
$\text{MSSIM}_Y = 0.9481$	$\text{MSSIM}_Y = 0.9634$	$\text{MSSIM}_Y = 0.9523$
$\Delta\hat{E}_{LAB} = 1.27$	$\Delta\hat{E}_{LAB} = 0.99$	$\Delta\hat{E}_{LAB} = 1.28$
VDP:	VDP:	VDP:

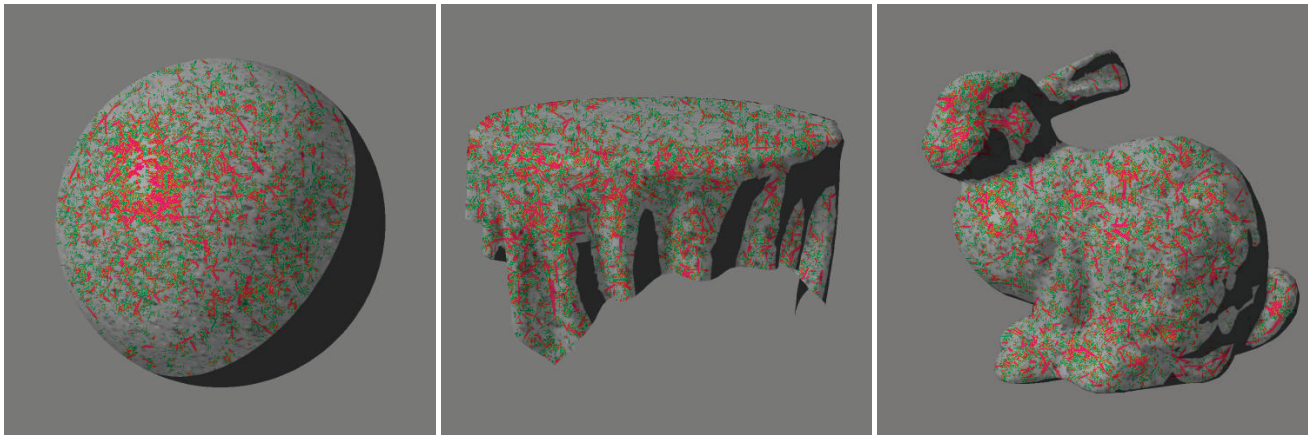
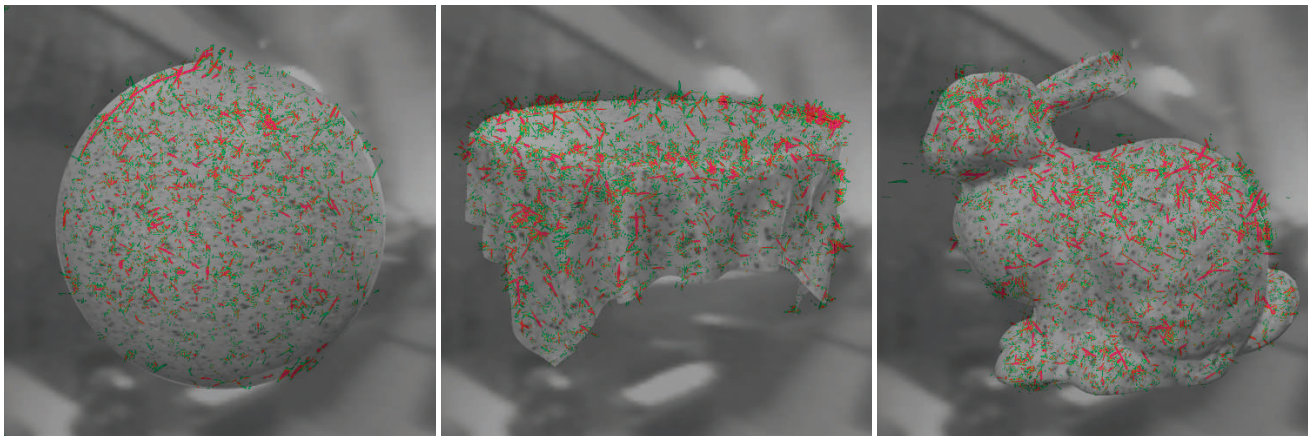


Figure 37: BTF sample **walkwayHDR** for **grace** environment.

Rendering using original data:

Rendering using the proposed method (C.R.= $\mathbf{1} : \mathbf{279}$):

$\text{MSSIM}_W = 0.9718$	$\text{MSSIM}_W = 0.9768$	$\text{MSSIM}_W = 0.9698$
$\text{MSSIM}_Y = 0.9653$	$\text{MSSIM}_Y = 0.9714$	$\text{MSSIM}_Y = 0.9628$
$\Delta\hat{E}_{LAB} = 1.37$	$\Delta\hat{E}_{LAB} = 1.28$	$\Delta\hat{E}_{LAB} = 1.40$
VDP:	VDP:	VDP:



4 Proposed Method Comparison with Existing BTF Compression Methods

A cutoff images from rendered images for point-light obtained using the proposed method were compared with results of three other existing BTF compression methods [Sattler et al. 2003] (**PCA**), [Filip and Haindl 2005] (**LM**), and [Müller et al. 2003] (**LPCA**) in terms of visual appearance and weighted MSSIM [Wang et al. 2004] in YCrCb color-space (weights: Y: 0.8, Cr: 0.1, Cb: 0.1). The test were performed for 3D object tablecloth and single point light from top-left.

Additionally there is a table for each sample summarising difference between original data and data rendered by the proposed method as well as reference methods PCA, LM, and LPCA. The difference is computed across all images in BTF sample and various distance measures were used:

- MSSIM_W - weighted MSSIM [Wang et al. 2004] computed in YCrCb color-space with weights (Y: 0.8, Cr: 0.1, Cb: 0.1).
- MSSIM_Y - weighted MSSIM computed in Luminance channel Y of YCrCb color-space.
- $\Delta\hat{E}$ - is average difference in CIE LAB color-space computed over all pixels.
- MSE_W - average weighted MSE (mean square error) in RGB color-space computed over all pixels with weights (R: 0.2126, G: 0.7152, B: 0.0722).

All distance measures were computed for as both mean and median from values for all BTF images.

Table also compares compression errors obtained by the proposed and the reference methods.

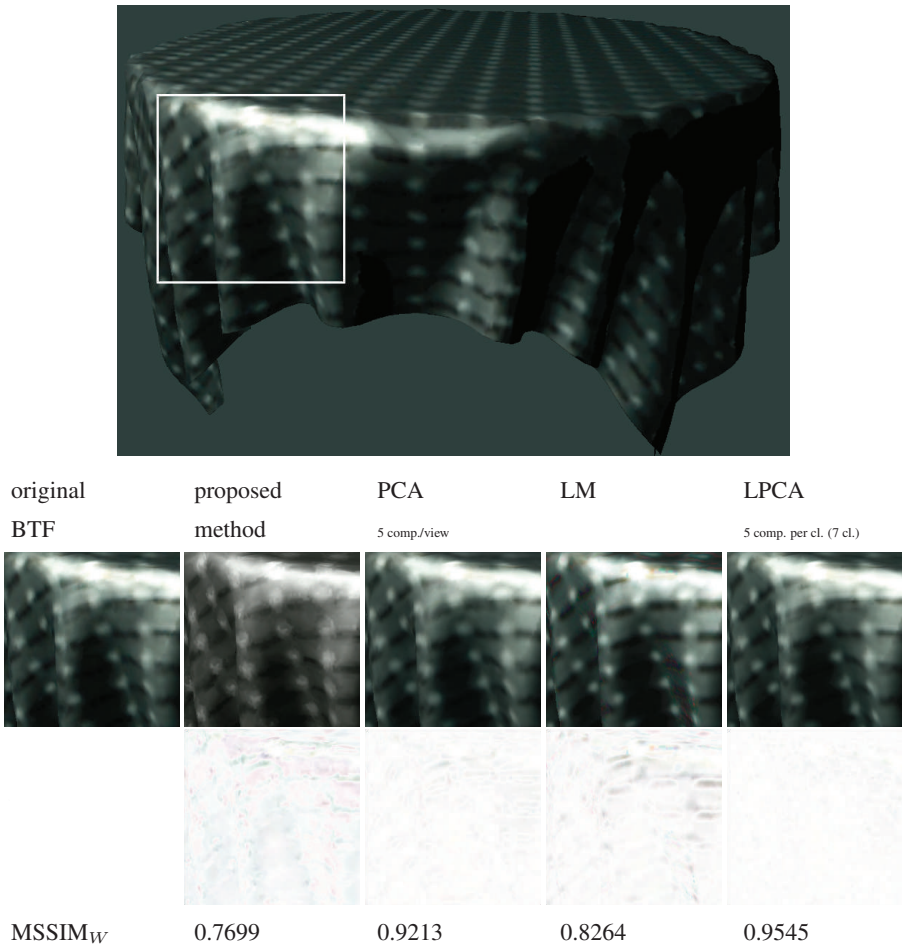


Figure 38: Visual comparison of the proposed method with different BTF compression methods for material **alu**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA . The second row show difference from original for the individual methods.

Table 1: Overall error in BTF sample **alu**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:1002**	1:14	1:16	1:275
median of MSSIM$_W$	0.2678	0.9761	0.9236	0.9821 †
median of MSSIM$_Y$	0.0881	0.9786	0.9313	0.9839 †
median of $\Delta\hat{E}$	19.82	3.80	6.94	4.14†
median of MSE_W	2496.5	29.0	129.1	15.9†
mean of MSSIM$_W$	0.2905	0.9294	0.8825	0.9409 †
mean of MSSIM$_Y$	0.1167	0.9396	0.8922	0.9496 †
mean of $\Delta\hat{E}$	27.88	5.21	8.75	4.14†
mean of MSE$_W$	8363.4	50.4	249.3	29.05†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

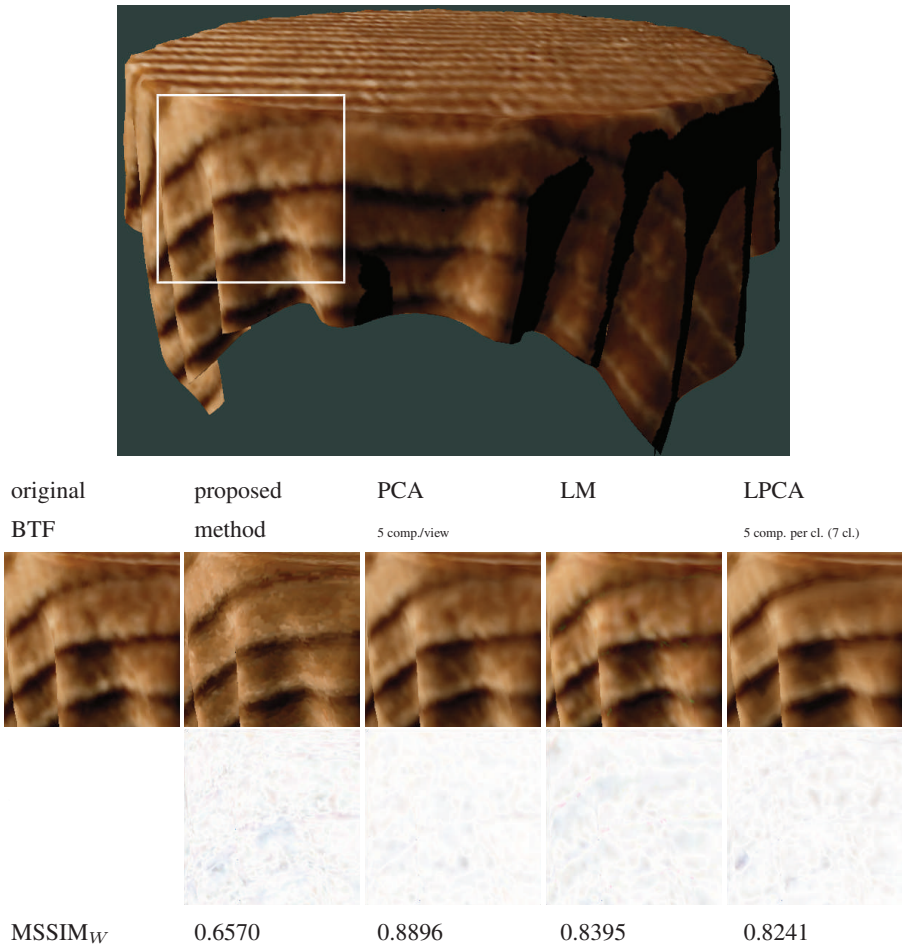


Figure 39: Visual comparison of the proposed method with different BTF compression methods for material **corduroy**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 2: Overall error in BTF sample **corduroy**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:418**	1:14	1:16	1:275
median of MSSIM$_W$	0.5672	0.9786	0.9572	0.9711 †
median of MSSIM$_Y$	0.5618	0.9887	0.9744	0.9869 †
median of $\Delta\hat{E}$	5.53	5.73	8.53	6.44†
median of MSE$_W$	139.4	64.8	148.4	111.7†
mean of MSSIM$_W$	0.5549	0.9210	0.8985	0.9160 †
mean of MSSIM$_Y$	0.5455	0.9282	0.9109	0.9254 †
mean of $\Delta\hat{E}$	5.80	6.74	9.78	7.25†
mean of MSE$_W$	174.8	79.0	230.7	132.7†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

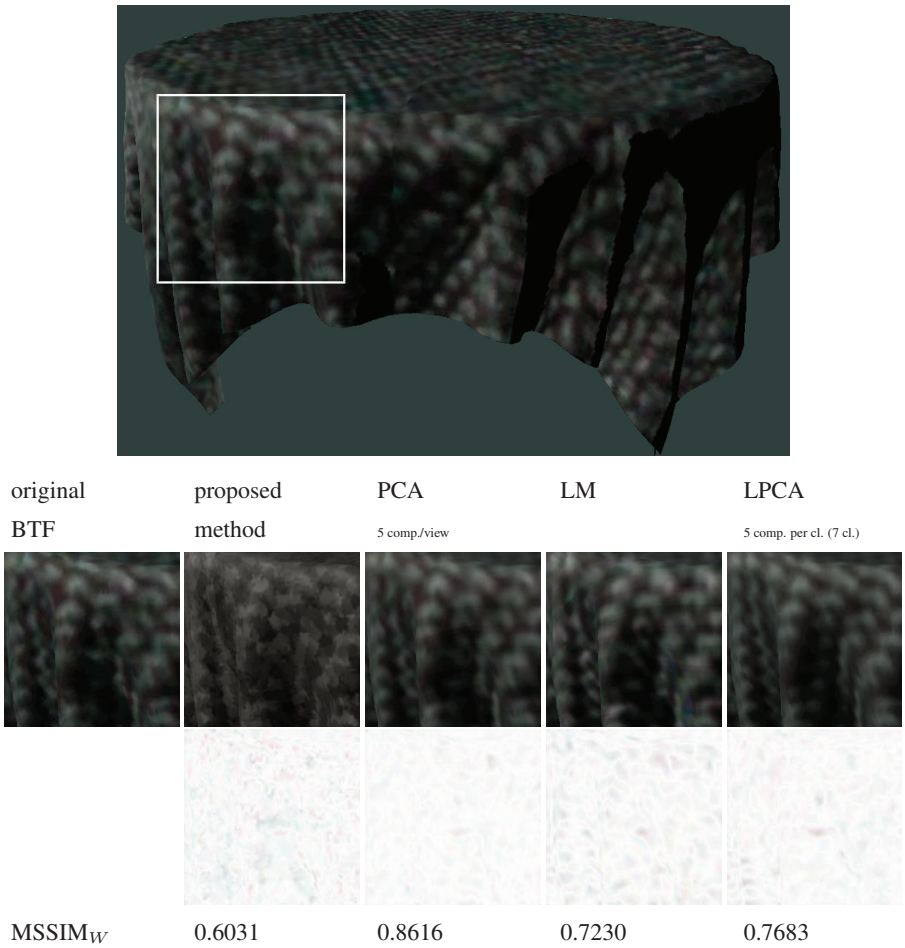


Figure 40: Visual comparison of the proposed method with different BTF compression methods for material **fabric1**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 3: Overall error in BTF sample **fabric1**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:363**	1:14	1:16	1:275
median of MSSIM$_W$	0.5328	0.9770	0.9400	0.9710 †
median of MSSIM$_Y$	0.4583	0.9207	0.9460	0.9740 †
median of $\Delta\hat{E}$	4.65	4.95	7.47	5.61†
median of MSE$_W$	110.4	70.0	139.24	98.47†
mean of MSSIM$_W$	0.5106	0.9152	0.8889	0.9149 †
mean of MSSIM$_Y$	0.4307	0.9207	0.8967	0.9217 †
mean of $\Delta\hat{E}$	4.87	6.45	8.93	7.1†
mean of MSE$_W$	130.6	78.9	187.1	116.78†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

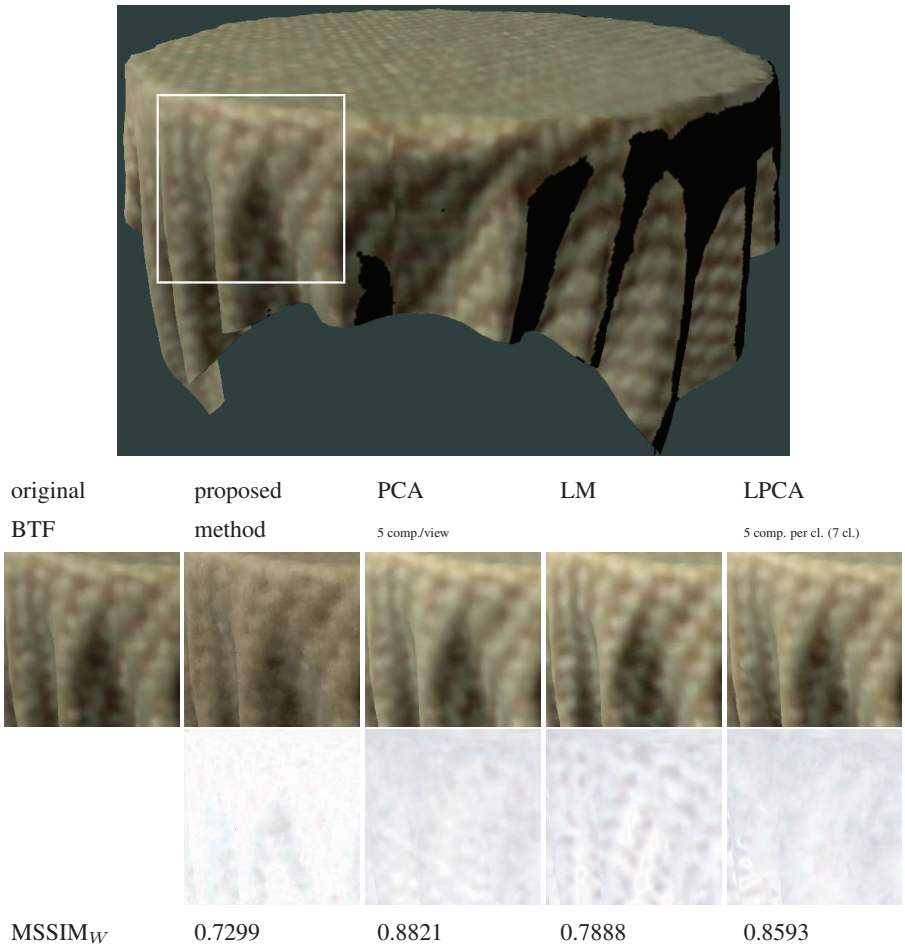


Figure 41: Visual comparison of the proposed method with different BTF compression methods for material **fabric2**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 4: Overall error in BTF sample **fabric2**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:710**	1:14	1:16	1:275
median of MSSIM$_W$	0.5822	0.9944	0.9900	0.9936 †
median of MSSIM$_Y$	0.5483	0.9952	0.9918	0.9945 †
median of $\Delta\hat{E}$	4.48	2.79	3.76	2.77†
median of MSE$_W$	75.9	35.6	82.5	39.5†
mean of MSSIM$_W$	0.5482	0.9936	0.9865	0.9925 †
mean of MSSIM$_Y$	0.5059	0.9947	0.9892	0.9937 †
mean of $\Delta\hat{E}$	4.59	2.92	4.18	2.95†
mean of MSE$_W$	91.98	43.3	127.2	51.9†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

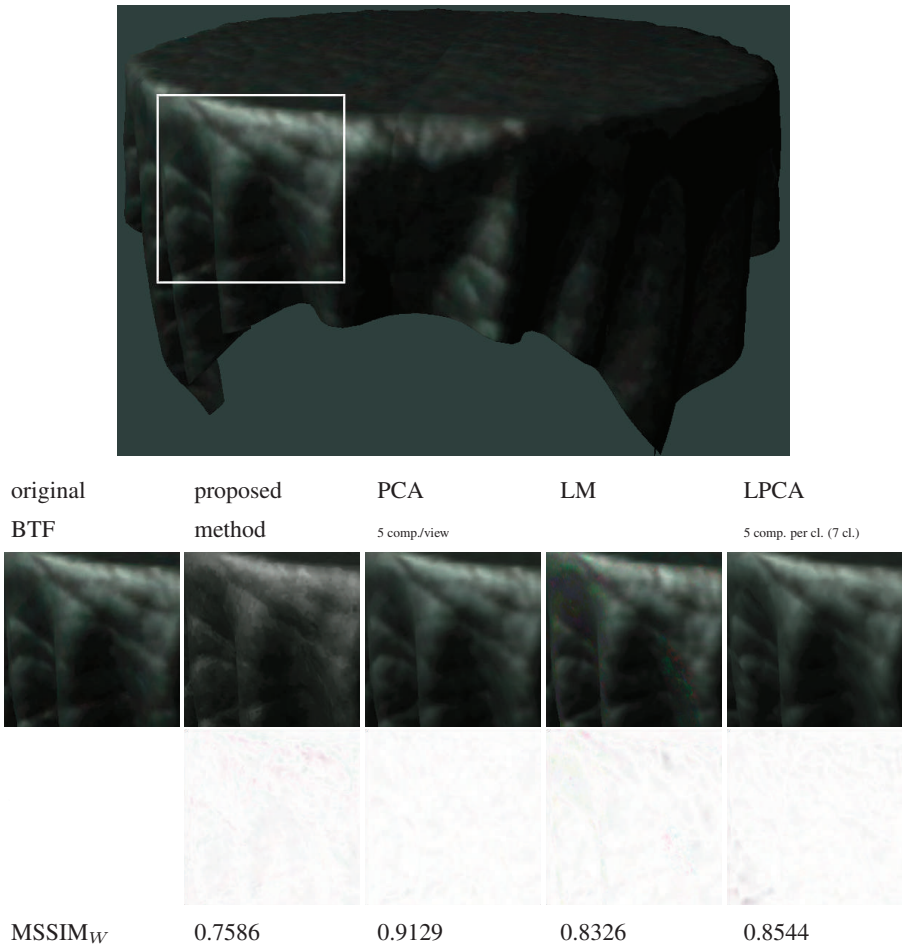


Figure 42: Visual comparison of the proposed method with different BTF compression methods for material **foil1**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 5: Overall error in BTF sample **foil1**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:2039**	1:14	1:16	1:275
median of MSSIM$_W$	0.5511	0.9922	0.9667	0.9889 †
median of MSSIM$_Y$	0.4564	0.9930	0.9708	0.9902 †
median of $\Delta\hat{E}$	2.49	2.80	4.83	3.01†
median of MSE$_W$	25.3	12.5	26.5	13.1†
mean of MSSIM$_W$	0.5391	0.9236	0.8929	0.9232 †
mean of MSSIM$_Y$	0.4445	0.9315	0.9017	0.9309 †
mean of $\Delta\hat{E}$	2.93	5.57	8.00	5.70†
mean of MSE$_W$	49.3	18.3	77.5	30.1†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

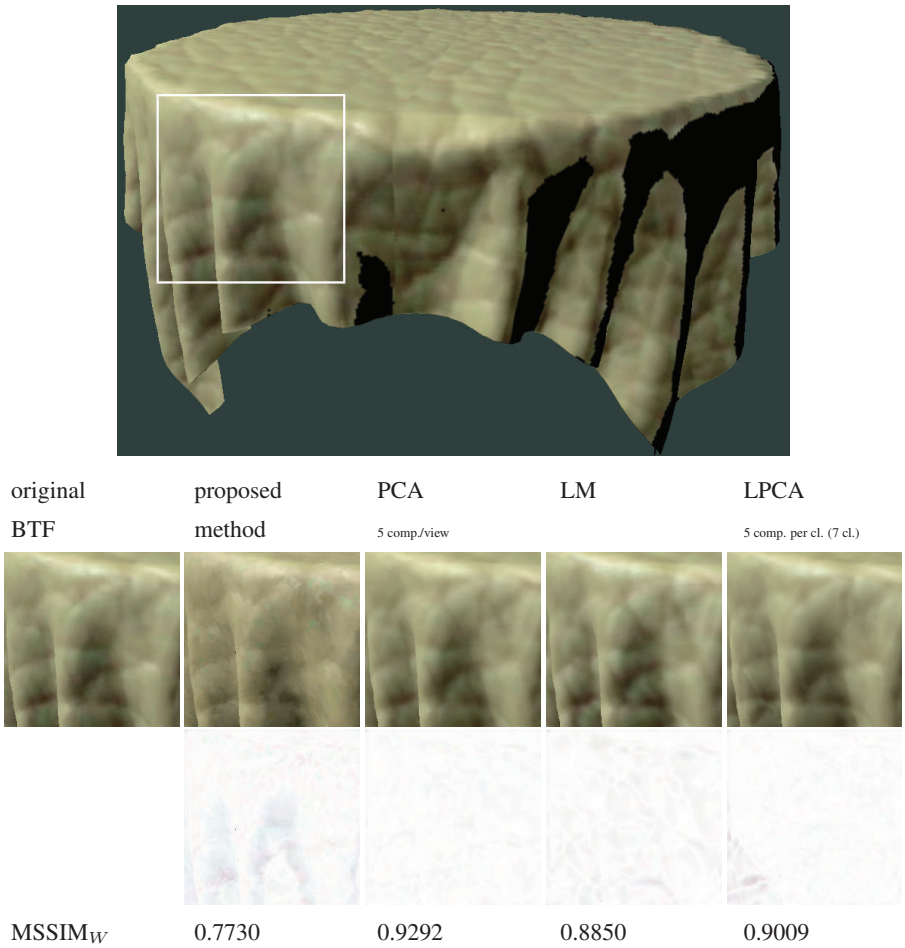


Figure 43: Visual comparison of the proposed method with different BTF compression methods for material **foil2**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 6: Overall error in BTF sample **foil2**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:1137**	1:14	1:16	1:275
median of MSSIM$_W$	0.5309	0.9968	0.9956	0.9961 †
median of MSSIM$_Y$	0.4674	0.9972	0.9963	0.9966 †
median of $\Delta\hat{E}$	3.88	2.36	2.55	2.07†
median of MSE$_W$	50.6	15.0	27.6	15.5†
mean of MSSIM$_W$	0.5152	0.9951	0.9899	0.9936 †
mean of MSSIM$_Y$	0.4455	0.9910	0.9921	0.9948 †
mean of $\Delta\hat{E}$	3.93	2.55	3.24	2.43†
mean of MSE$_W$	67.5	23.0	70.8	29.3†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

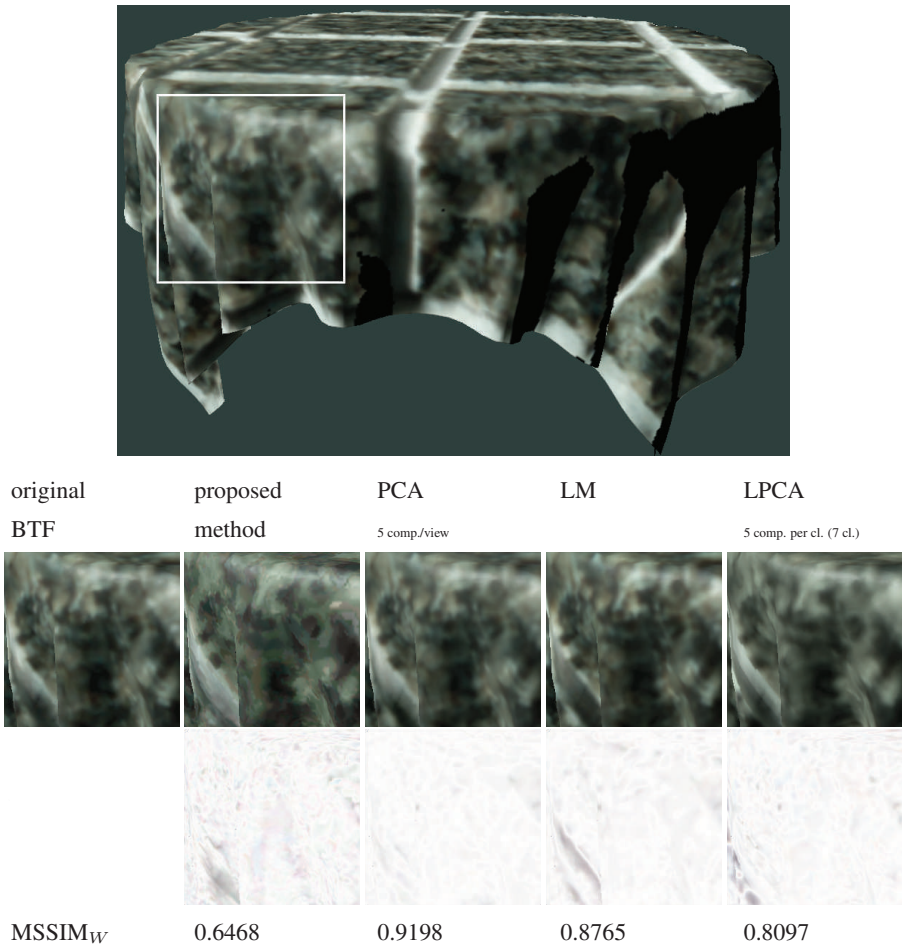


Figure 44: Visual comparison of the proposed method with different BTF compression methods for material **impalla**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 7: Overall error in BTF sample **impalla**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:523**	1:14	1:16	1:275
median of MSSIM$_W$	0.4649	0.9832	0.9727	0.9795 †
median of MSSIM$_Y$	0.4610	0.9866	0.9775	0.9840 †
median of $\Delta\hat{E}$	9.09	4.83	6.67	5.05†
median of MSE$_W$	671.4	193.0	405.5	177.3†
mean of MSSIM$_W$	0.4419	0.9707	0.9594	0.9701 †
mean of MSSIM$_Y$	0.4313	0.9758	0.9659	0.9758 †
mean of $\Delta\hat{E}$	9.21	5.33	7.31	5.28†
mean of MSE$_W$	753.2	206.4	528.4	197.3†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

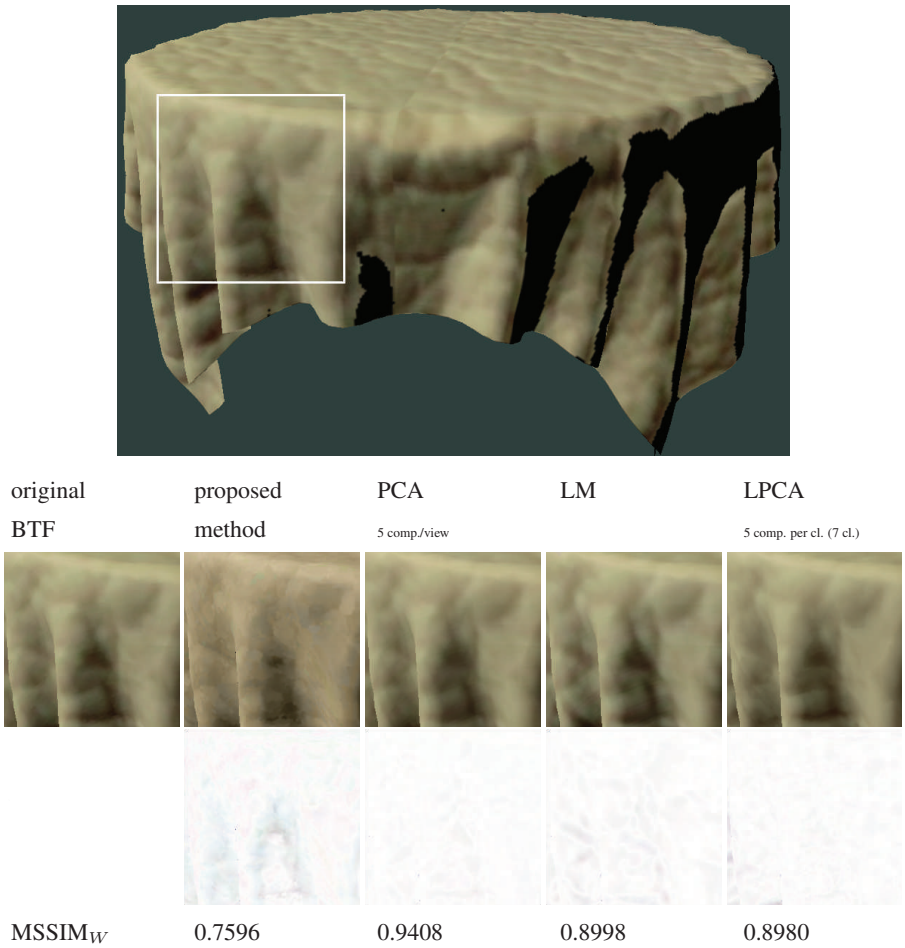


Figure 45: Visual comparison of the proposed method with different BTF compression methods for material **leather**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 8: Overall error in BTF sample **leather**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:522**	1:14	1:16	1:275
median of MSSIM$_W$	0.4926	0.9976	0.9970	0.9967 †
median of MSSIM$_Y$	0.4285	0.9979	0.9975	0.9972 †
median of $\Delta\hat{E}$	4.81	2.17	2.13	1.96†
median of MSE$_W$	77.8	10.4	18.4	14.2†
mean of MSSIM$_W$	0.4794	0.9936	0.9915	0.9936 †
mean of MSSIM$_Y$	0.4093	0.9945	0.9932	0.9948 †
mean of $\Delta\hat{E}$	4.82	2.46	2.76	2.32†
mean of MSE$_W$	98.2	17.3	43.8	25.4†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

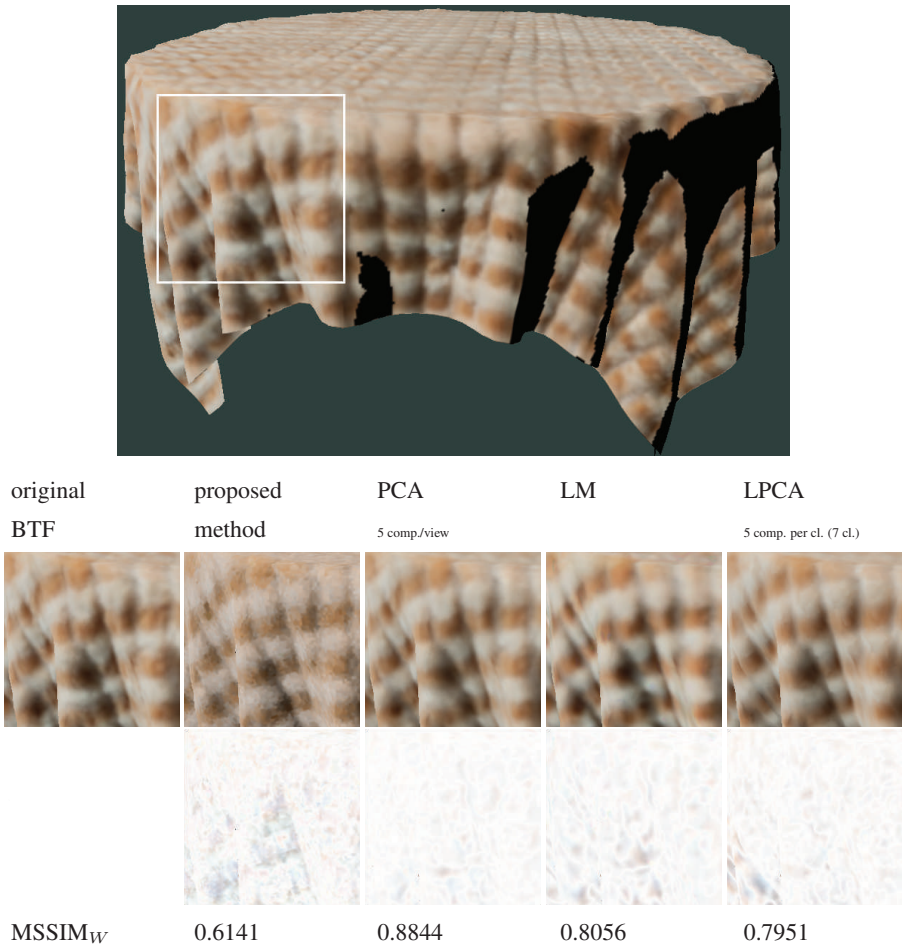


Figure 46: Visual comparison of the proposed method with different BTF compression methods for material **proposte**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 9: Overall error in BTF sample **proposte**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:806**	1:14	1:16	1:275
median of MSSIM$_W$	0.7353	0.9926	0.9832	0.9898 †
median of MSSIM$_Y$	0.6902	0.9953	0.9887	0.9942 †
median of $\Delta\hat{E}$	6.61	3.66	5.89	4.12†
median of MSE$_W$	271.3	78.5	212.3	121.1†
mean of MSSIM$_W$	0.7274	0.9897	0.9786	0.9876 †
mean of MSSIM$_Y$	0.6795	0.9929	0.9849	0.9921 †
mean of $\Delta\hat{E}$	6.62	3.97	6.33	4.29†
mean of MSE$_W$	291.1	102.2	295.5	145.3†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

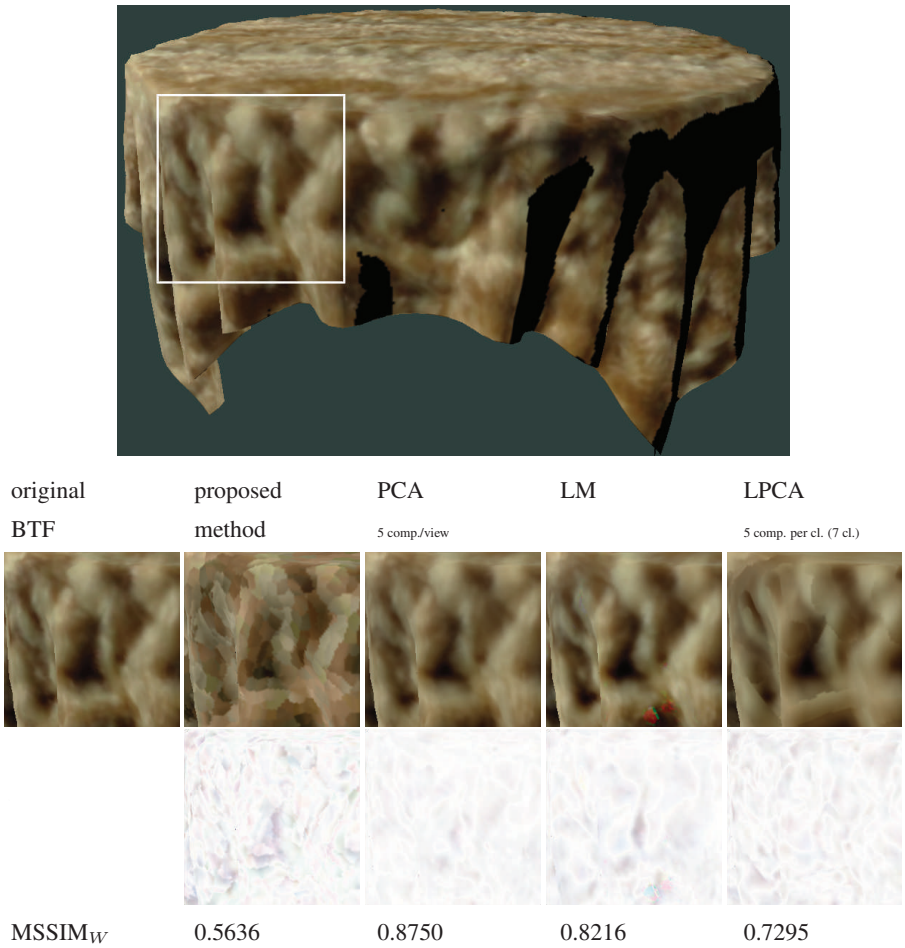


Figure 47: Visual comparison of the proposed method with different BTF compression methods for material **pulli**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 10: Overall error in BTF sample **pulli**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:264**	1:14	1:16	1:275
median of MSSIM$_W$	0.4565	0.9902	0.9828	0.9810 †
median of MSSIM$_Y$	0.3924	0.9932	0.9874	0.9878 †
median of $\Delta\hat{E}$	6.06	4.45	5.81	6.08†
median of MSE$_W$	196.51	94.82	176.0	221.8†
mean of MSSIM$_W$	0.4548	0.9641	0.9502	0.9552 †
mean of MSSIM$_Y$	0.3932	0.9679	0.9560	0.9625 †
mean of $\Delta\hat{E}$	6.05	5.34	7.31	6.99†
mean of MSE$_W$	210.4	4.45	258.9	261.4†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

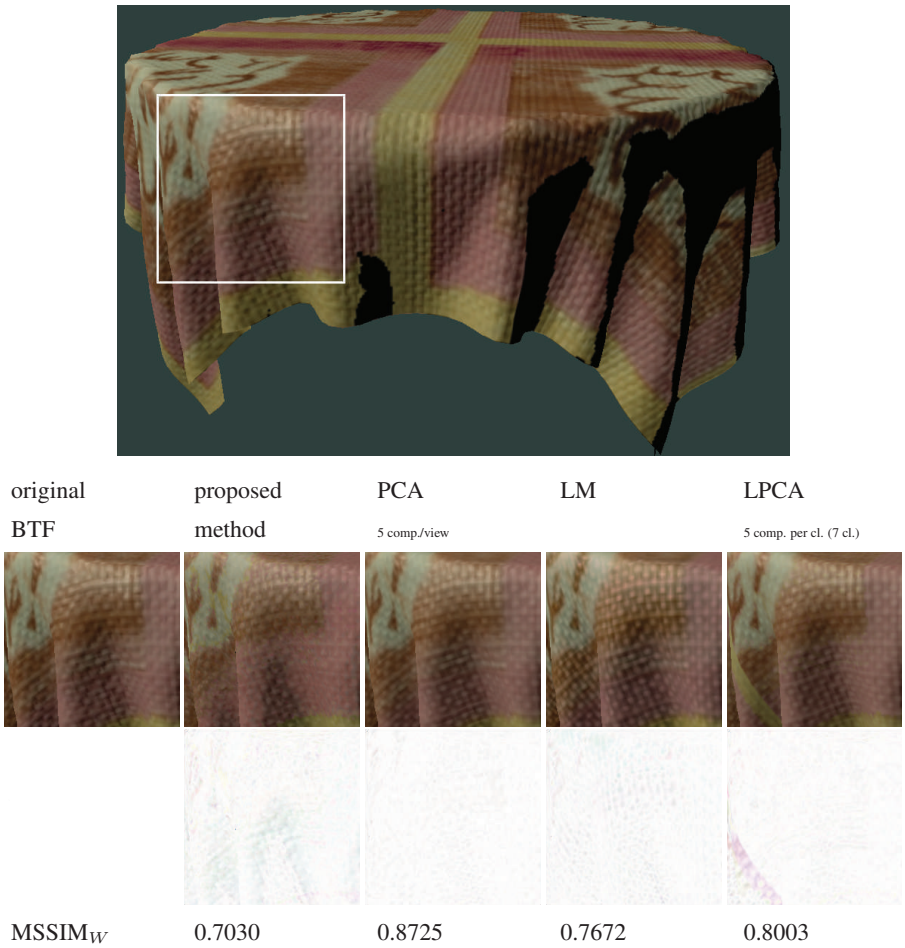


Figure 48: Visual comparison of the proposed method with different BTF compression methods for material **wallpaper**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 11: Overall error in BTF sample **wallpaper**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:728**	1:14	1:16	1:275
median of MSSIM$_W$	0.1149	0.9910	0.9797	0.9876 †
median of MSSIM$_Y$	0.0226	0.9934	0.9828	0.9917 †
median of $\Delta\hat{E}$	38.47	2.92	4.40	3.69†
median of MSE$_W$	7304.9	54.6	94.2	64.8†
mean of MSSIM$_W$	0.1155	0.9552	0.9403	0.9626 †
mean of MSSIM$_Y$	0.0233	0.9592	0.9460	0.9685 †
mean of $\Delta\hat{E}$	39.24	4.10	5.90	4.53†
mean of MSE$_W$	8745.83	64.8	148.7	81.7†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

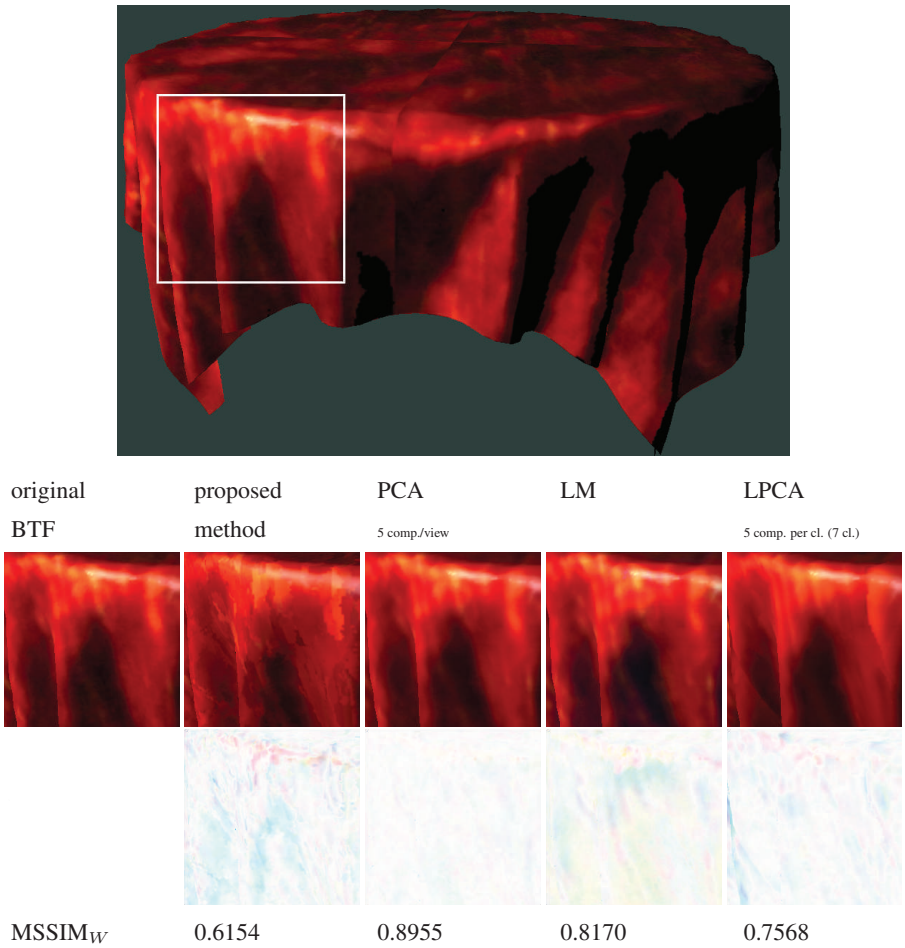


Figure 49: Visual comparison of the proposed method with different BTF compression methods for material **wood1**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 12: Overall error in BTF sample **wood1**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:352**	1:14	1:16	1:275
median of MSSIM$_W$	0.4590	0.9477	0.9143	0.9437 †
median of MSSIM$_Y$	0.4292	0.9524	0.9328	0.9549 †
median of $\Delta\hat{E}$	4.80	6.82	11.57	8.02†
median of MSE$_W$	38.0	19.8	38.98	35.9†
mean of MSSIM$_W$	0.4559	0.8265	0.7890	0.8108 †
mean of MSSIM$_Y$	0.4273	0.8291	0.7959	0.8144 †
mean of $\Delta\hat{E}$	4.64	9.22	14.15	10.60†
mean of MSE$_W$	44.2	22.2	53.58	38.85†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

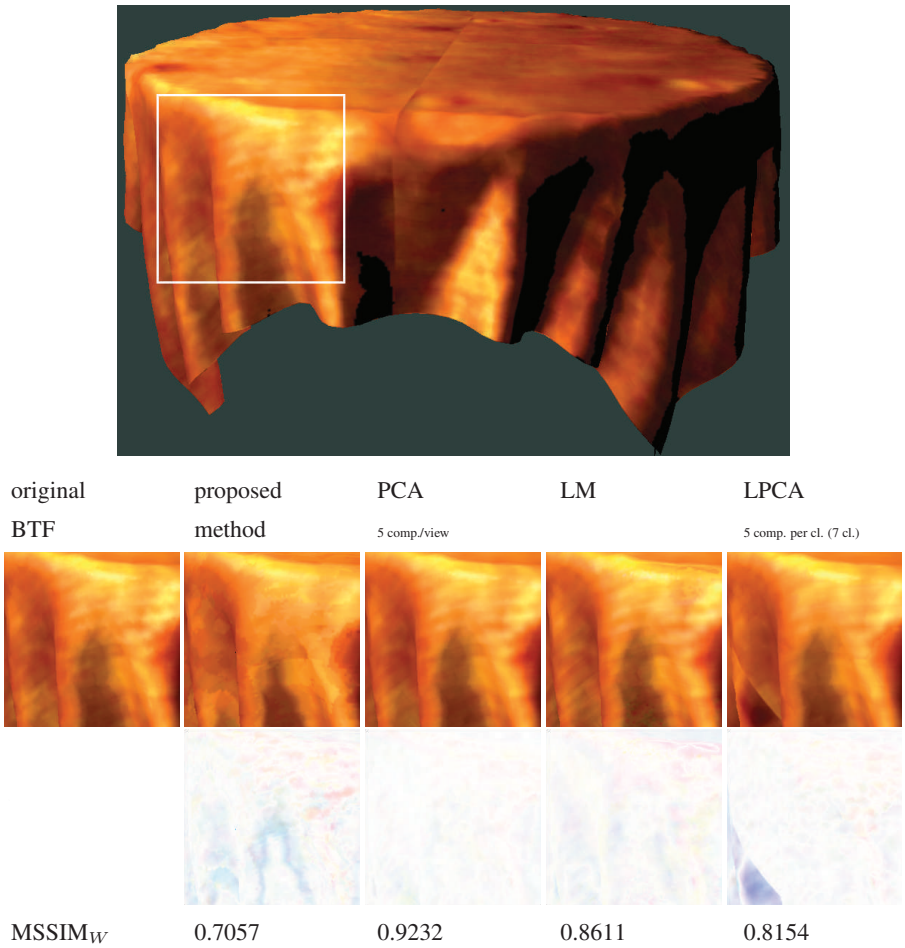


Figure 50: Visual comparison of the proposed method with different BTF compression methods for material **wood2**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 13: Overall error in BTF sample **wood2**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:278**	1:14	1:16	1:275
median of MSSIM$_W$	0.1889	0.9929	0.9315	0.9923 †
median of MSSIM$_Y$	0.1122	0.9954	0.9330	0.9947 †
median of $\Delta\hat{E}$	51.51	3.43	9.68	3.22†
median of MSE$_W$	5379.6	17.8	86.0	17.7†
mean of MSSIM$_W$	0.2118	0.9540	0.8922	0.9570 †
mean of MSSIM$_Y$	0.1415	0.9578	0.8955	0.9608 †
mean of $\Delta\hat{E}$	53.29	3.43	10.96	4.49†
mean of MSE$_W$	8839.0	20.5	197.2	23.1†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

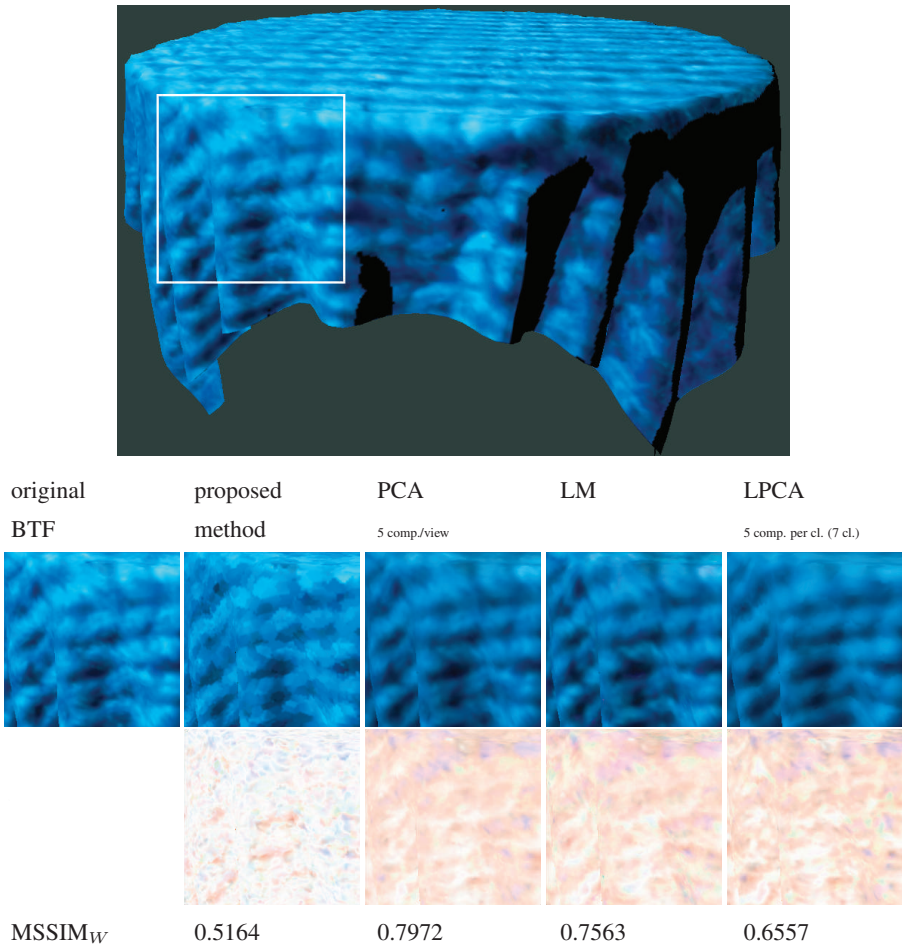


Figure 51: Visual comparison of the proposed method with different BTF compression methods for material **wool**. The first row from left to right original, compressed using the proposed method, methods PCA, LM, and LPCA. The second row show difference from original for the individual methods.

Table 14: Overall error in BTF sample **wool**

distance measure	proposed	PCA	LM	LPCA
Compression ratio	**1:233**	1:14	1:16	1:275
median of MSSIM$_W$	0.4152	0.9919	0.9819	0.9870 †
median of MSSIM$_Y$	0.3953	0.9958	0.9881	0.9941 †
median of $\Delta\hat{E}$	6.85	3.81	5.41	4.71†
median of MSE$_W$	177.9	77.2	136.2	131.6†
mean of MSSIM$_W$	0.4130	0.9686	0.9534	0.9643 †
mean of MSSIM$_Y$	0.3911	0.9718	0.9587	0.9706 †
mean of $\Delta\hat{E}$	6.75	4.35	6.25	5.25†
mean of MSE$_W$	200.9	88.3	174.4	154.2†

† sample computed only in resolution 128×128 pixels due to the method's extreme memory and computational demands

Table 15: HDR samples comparison

material	ceilingHDR	floortileHDR	pinktileHDR	walkwayHDR
Compression ratio	**1:780**	**1:399**	**1:2397**	**1:279**
median of MSSIM_W	0.5389	0.7716	0.9825	0.8084
median of MSSIM_Y	0.4283	0.7155	0.9784	0.7630
median of $\Delta\hat{E}$	0.0634	0.0046	0.0011	0.0193
median of MSE_W	0.0564	0.0004	0.0000	0.0047
mean of MSSIM_W	0.5295	0.7432	0.9660	0.7796
mean of MSSIM_Y	0.4175	0.6810	0.9579	0.7283
mean of $\Delta\hat{E}$	0.0700	0.0062	0.0016	0.0264
mean of MSE_W	0.0848	0.0019	0.0001	0.0251

5 Apparent BRDFs Comparison

In this section the original apparent BRDFs $F_{\mathbf{x}}$ and the results of the model are shown for ten tested BTF samples. The odd columns in each image are resampled BTF data into $[\alpha, \beta, \theta_v, \varphi_v]$ representation (see Fig.4 in article) while the even columns illustrates fitting of the proposed model. The individual angles discretization was set to $n_\alpha = 13$, $n_\beta = 13$, $n_{\theta_v} = 7$, and $n_{\varphi_v} = 16$.

Figure 52: A comparison of original (odd columns) apparent BRDF $F_{\mathbf{x}}$ and its approximation by the proposed model (even columns).

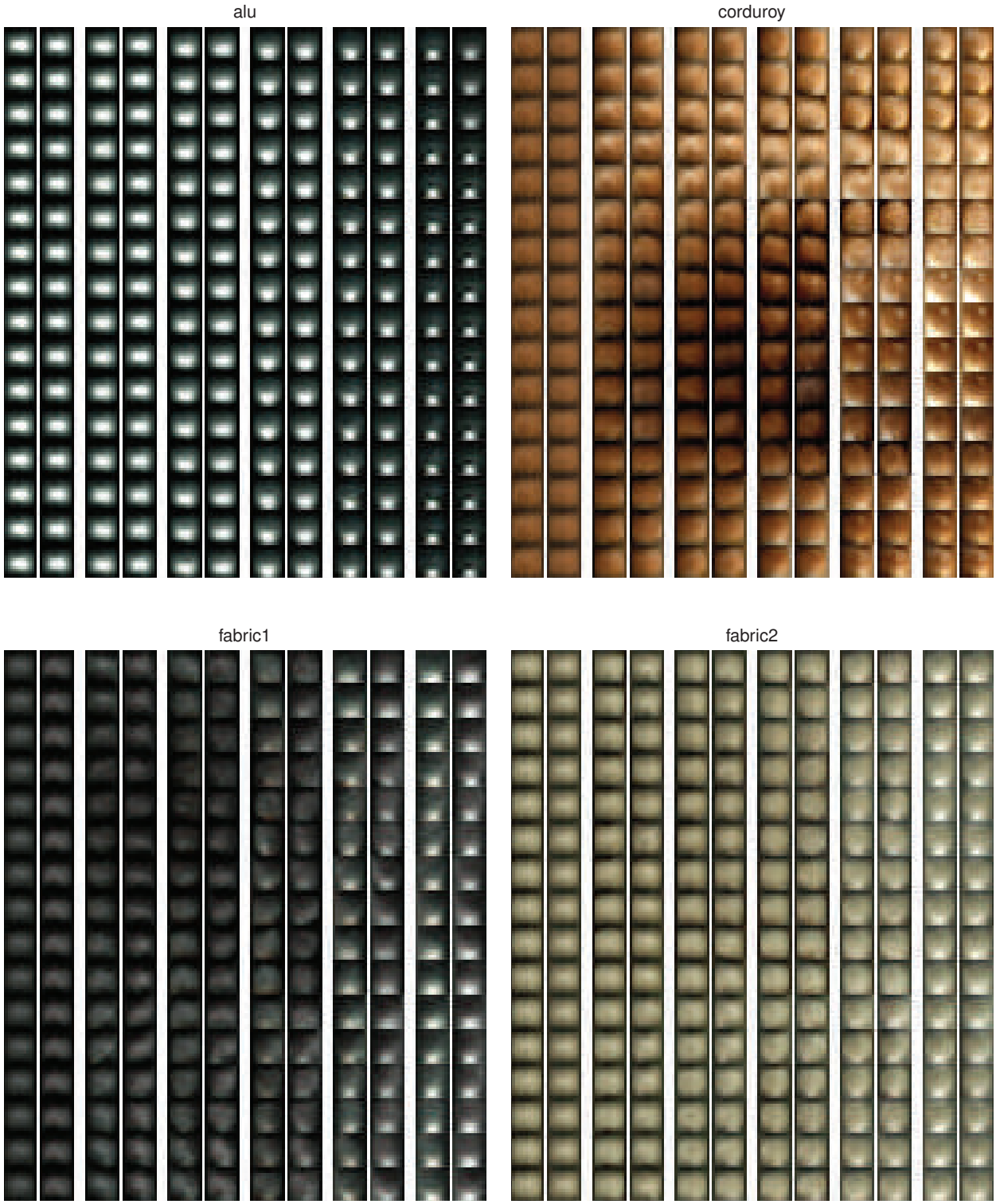


Figure 53: A comparison of original (odd columns) apparent BRDF $F_{\mathbf{x}}$ and its approximation by the proposed model (even columns).

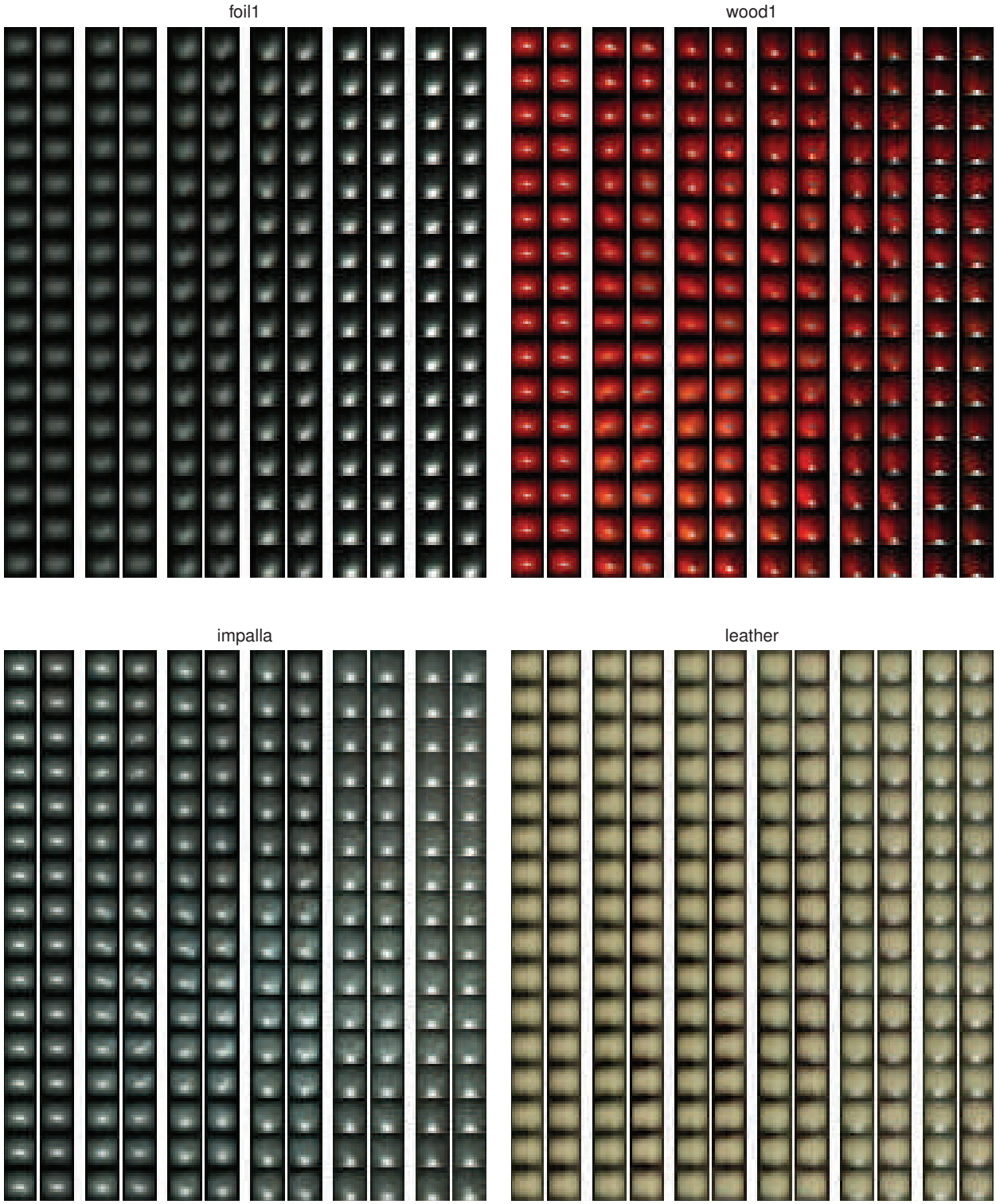


Figure 54: A comparison of original (odd columns) apparent BRDF $F_{\mathbf{x}}$ and its approximation by the proposed model (even columns).