DeepBRDF: A Deep Representation for Manipulating Measured BRDF

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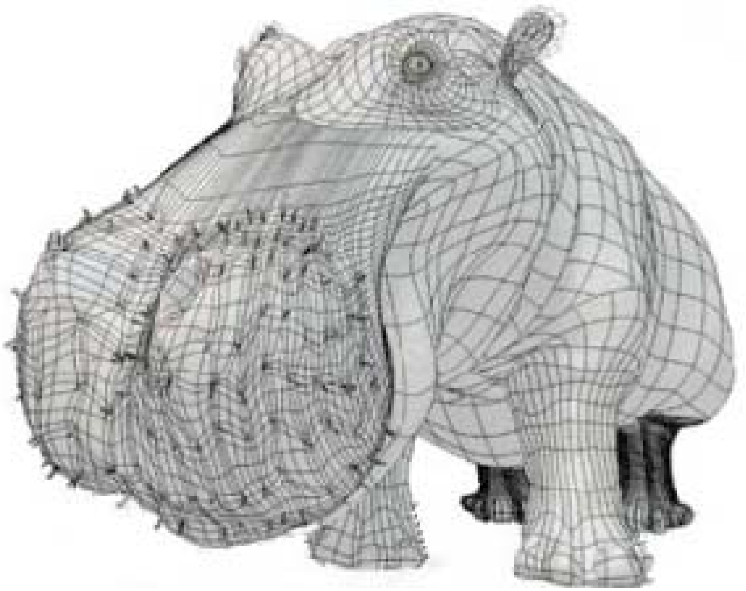
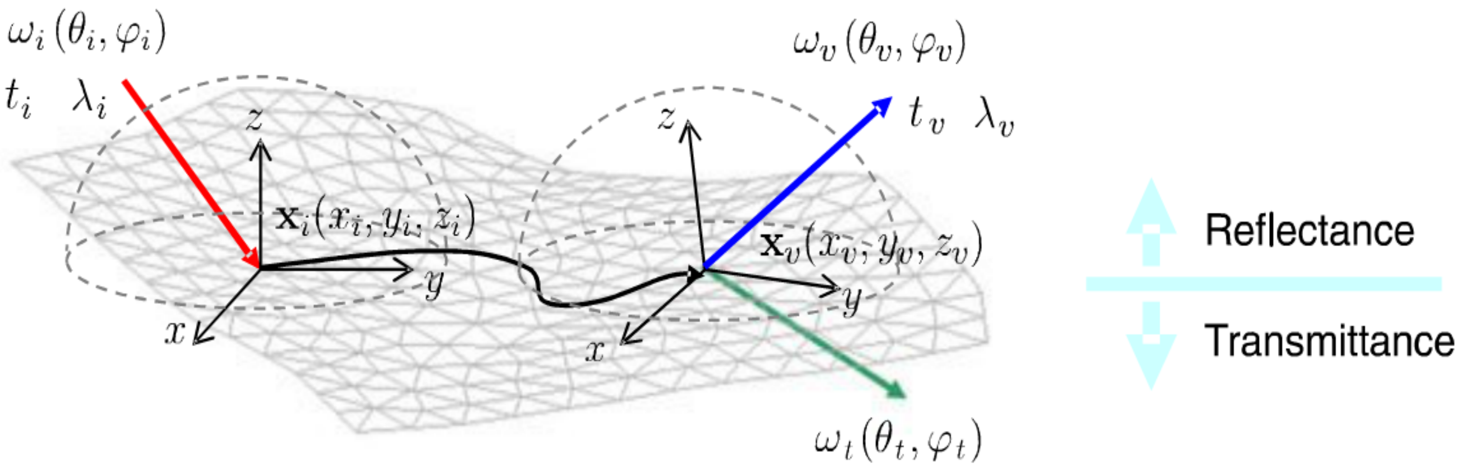
Material Apperance



+ Material

General Reflectance Function

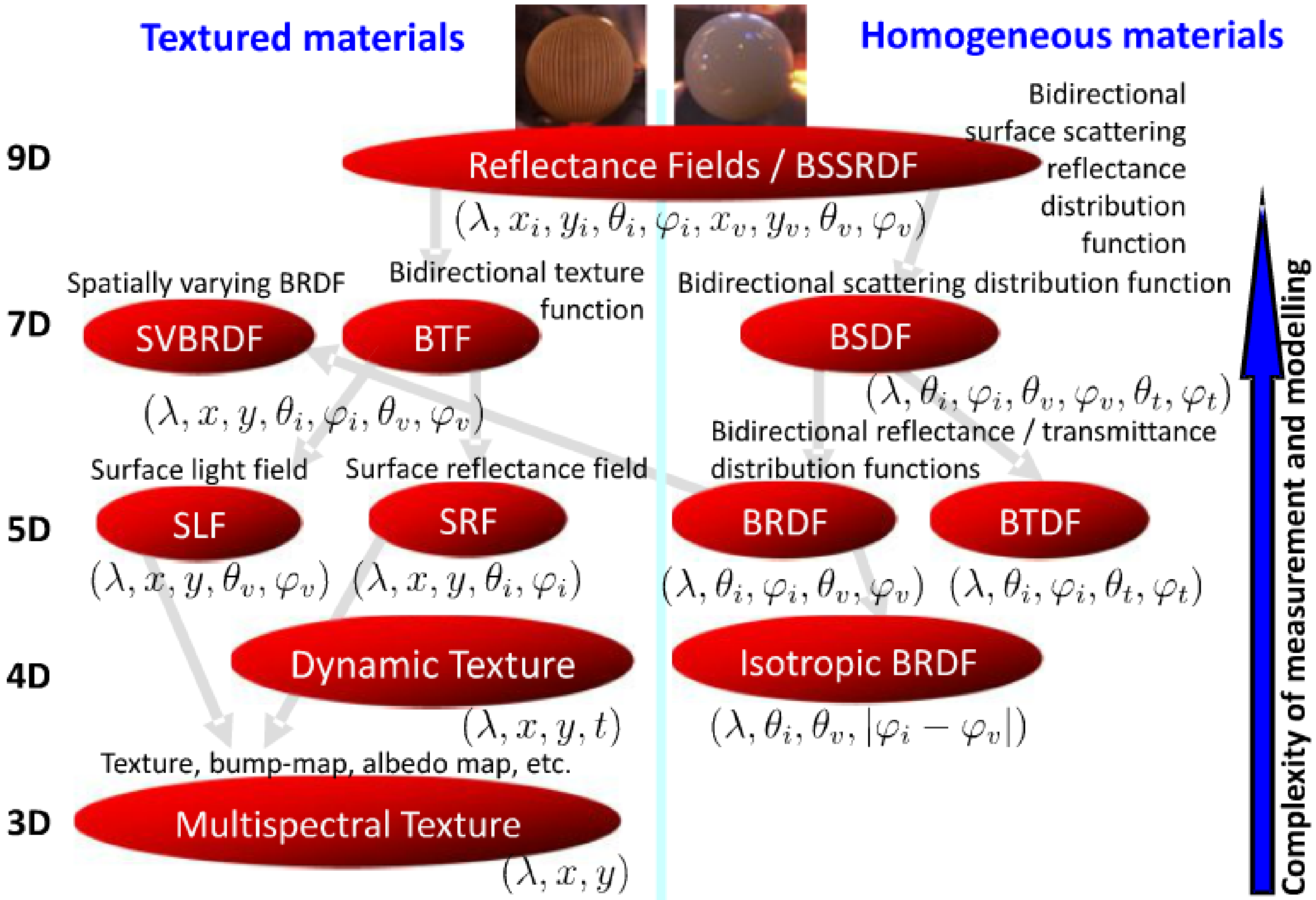
- A real material's surface reflectance function is a very complex function of 16 variables.



general reflectance function (GRF)

$$Y_r^{GRF} = GRF(\lambda_i, x_i, y_i, z_i, t_i, \theta_i, \varphi_i, \lambda_v, x_v, y_v, z_v, t_v, \theta_v, \varphi_v, \theta_t, \varphi_t)$$

Taxonomy

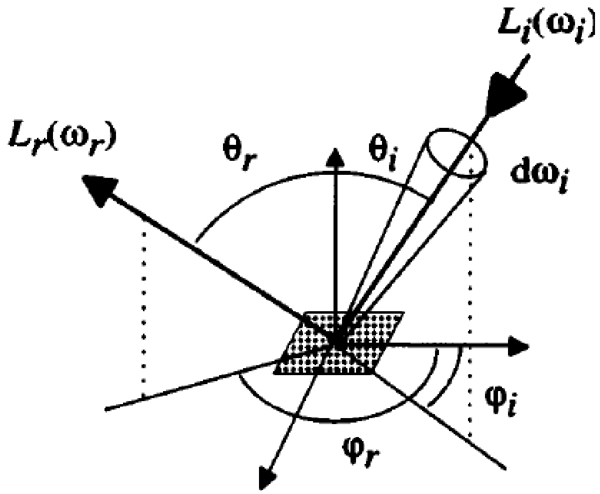


Textured materials
Homogeneous materials
Bidirectional surface scattering reflectance distribution function
9D
Reflectance Fields / BSSRDF
$(\lambda, x_i, y_i, \theta_i, \varphi_i, x_v, y_v, \theta_v, \varphi_v)$
Spatially varying BRDF
Bidirectional texture function
Bidirectional scattering distribution function
7D
SVBRDF
BTF
BSDF
$(\lambda, x, y, \theta_i, \varphi_i, \theta_v, \varphi_v)$
$(\lambda, \theta_i, \varphi_i, \theta_v, \varphi_v, \theta_t, \varphi_t)$
Bidirectional reflectance / transmittance distribution functions
Surface light field
Surface reflectance field
5D
SLF
SRF
BRDF
BTDF
$(\lambda, x, y, \theta_v, \varphi_v)$
$(\lambda, x, y, \theta_i, \varphi_i)$
$(\lambda, \theta_i, \varphi_i, \theta_v, \varphi_v)$
$(\lambda, \theta_i, \varphi_i, \theta_t, \varphi_t)$
4D
Dynamic Texture
Isotropic BRDF
(λ, x, y, t)
$(\lambda, \theta_i, \theta_v, |\varphi_i - \varphi_v|)$
Texture, bump-map, albedo map, etc.
3D
Multispectral Texture
(λ, x, y)
Complexity of measurement and modelling

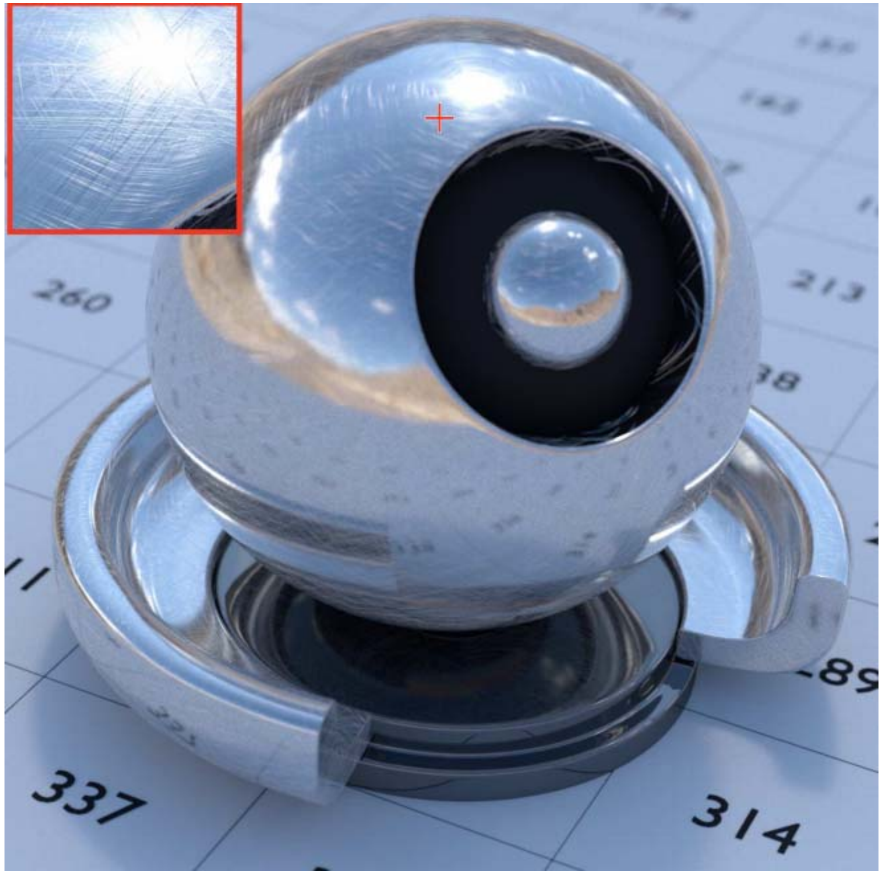
BRDF

- Bidirectional Reflectance Distribution Function
- BRDF f_r describes surface reflection at a point x for light incident from direction $\omega_i = (\theta_i, \varphi_i)$ reflected into direction $\omega_r = (\theta_r, \varphi_r)$

$$f_r(\vec{\omega}_i \rightarrow \vec{\omega}_r) \equiv \frac{L_r(\vec{\omega}_r)}{L_i(\vec{\omega}_i)\cos\theta_i \, d\omega_i}$$

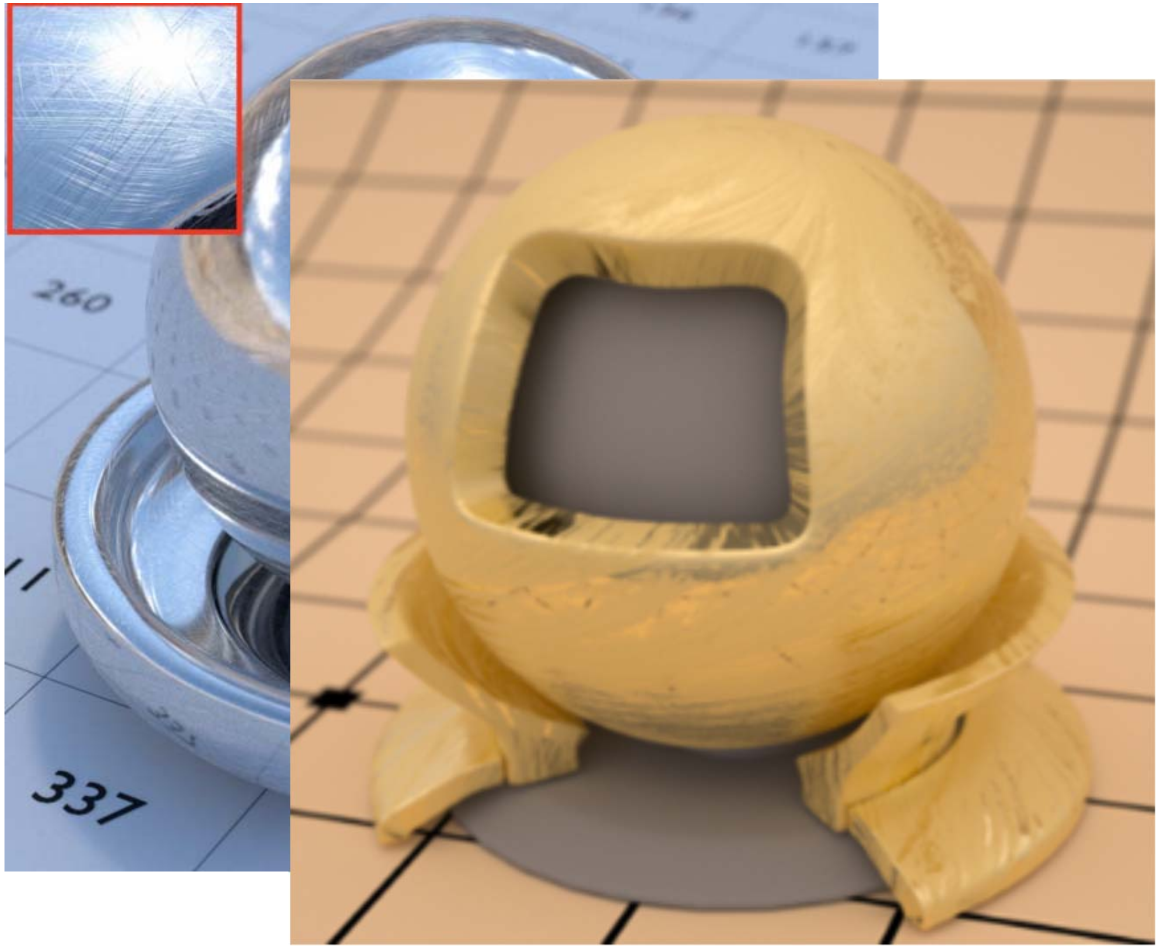


Material Apperance



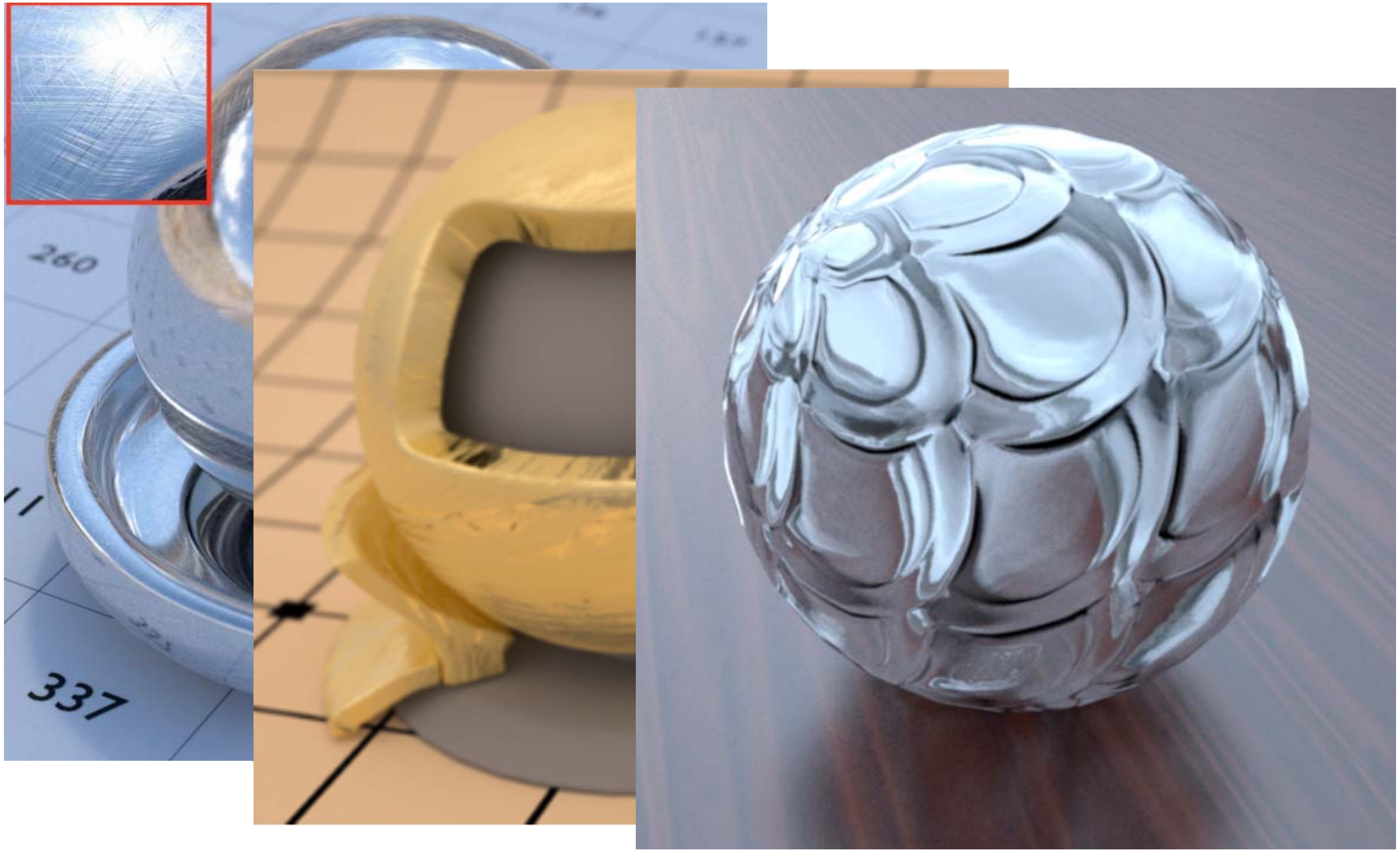
Raymond et al. – Multi-Scale Rendering of Scratched Materials using a Structured SV-BRDF Model. 2016

Material Apperance



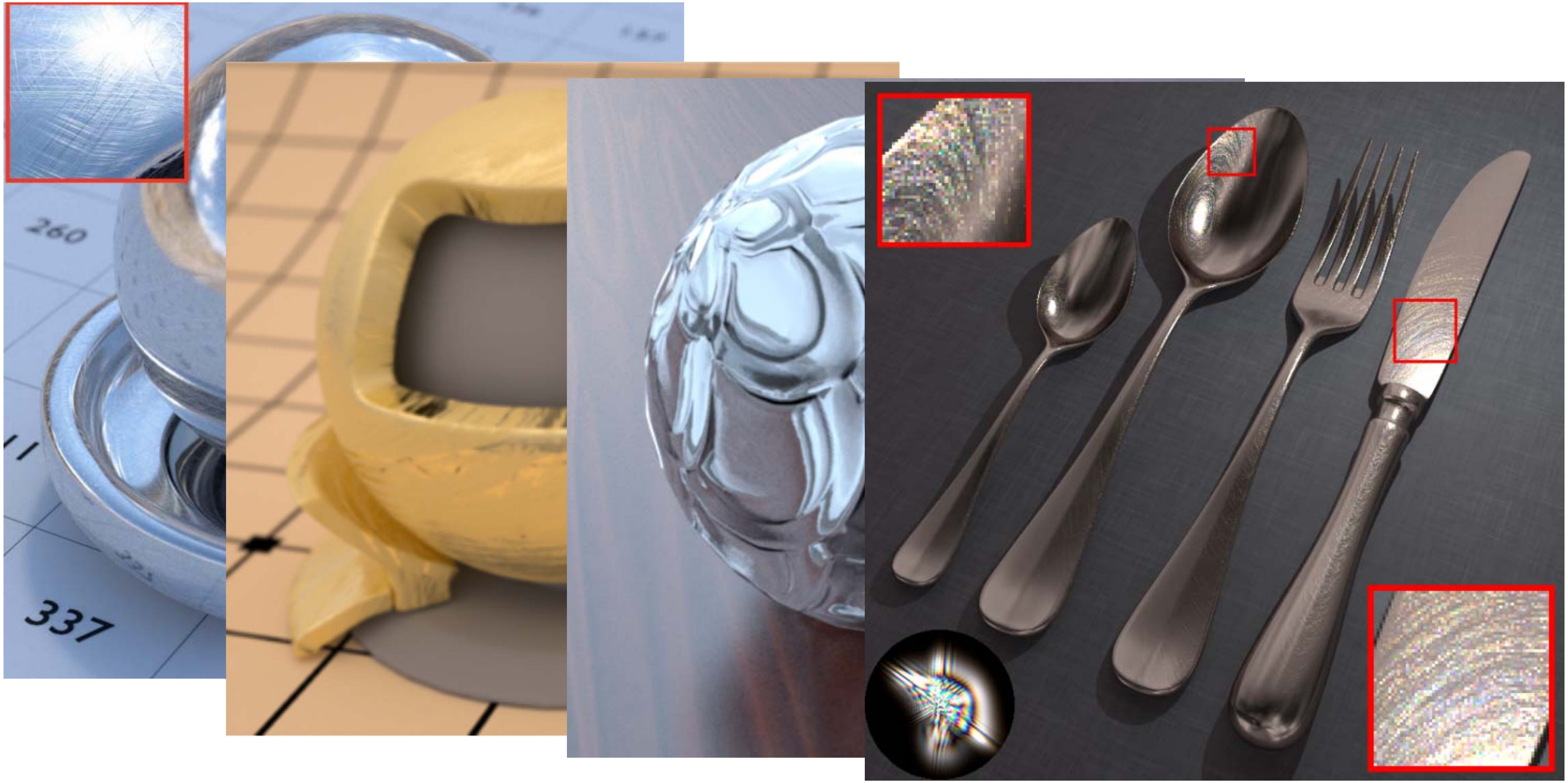
Heitz et al. - Multiple-Scattering Microfacet BSDFs with the Smith Model, SIGGRAPH 2016

Material Apperance



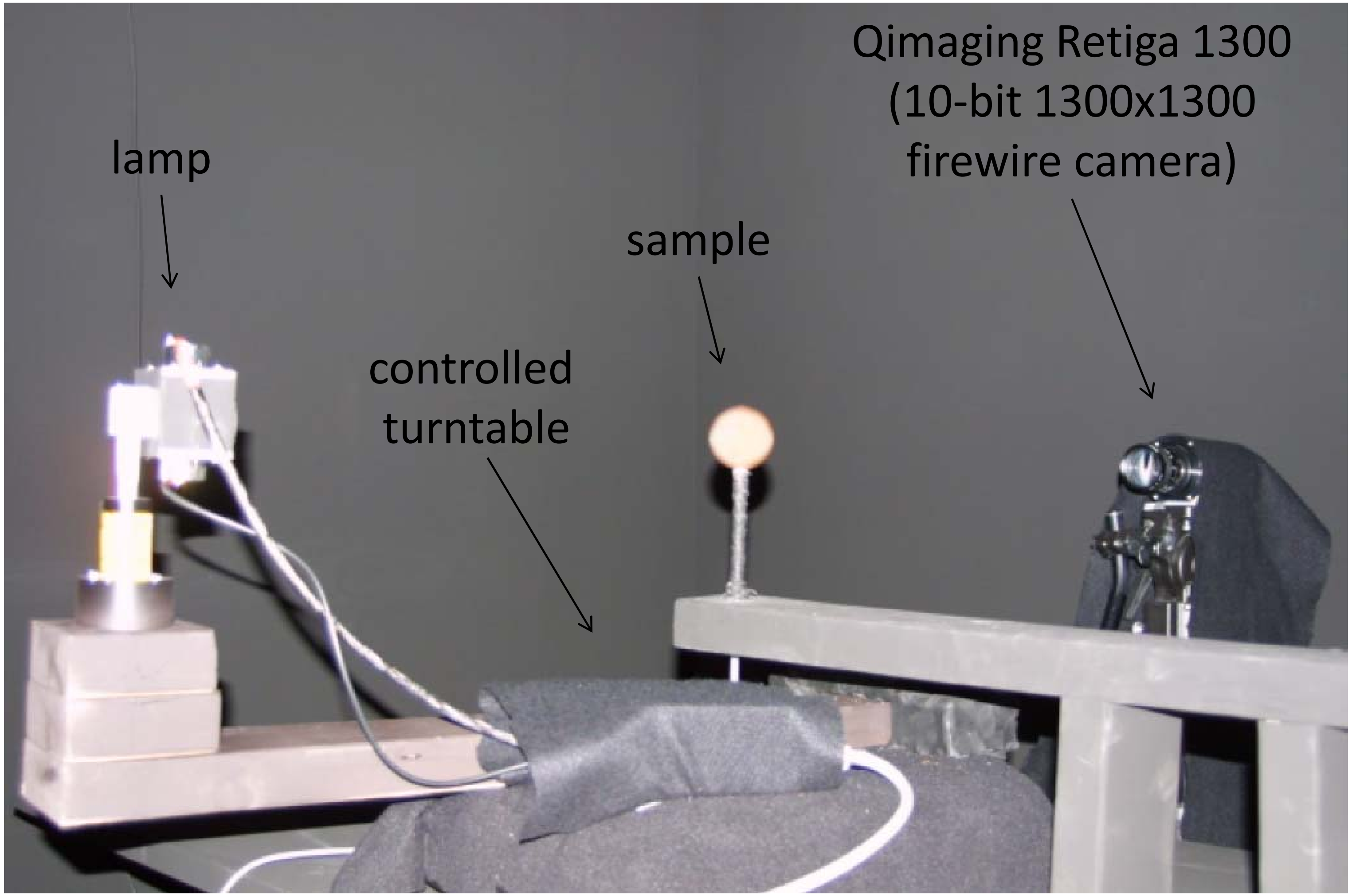
Vincent Schussler et al. - Microfacet-based normal mapping for robust Monte Carlo path tracing, SIGGRAPH Asia 2017

Material Apperance

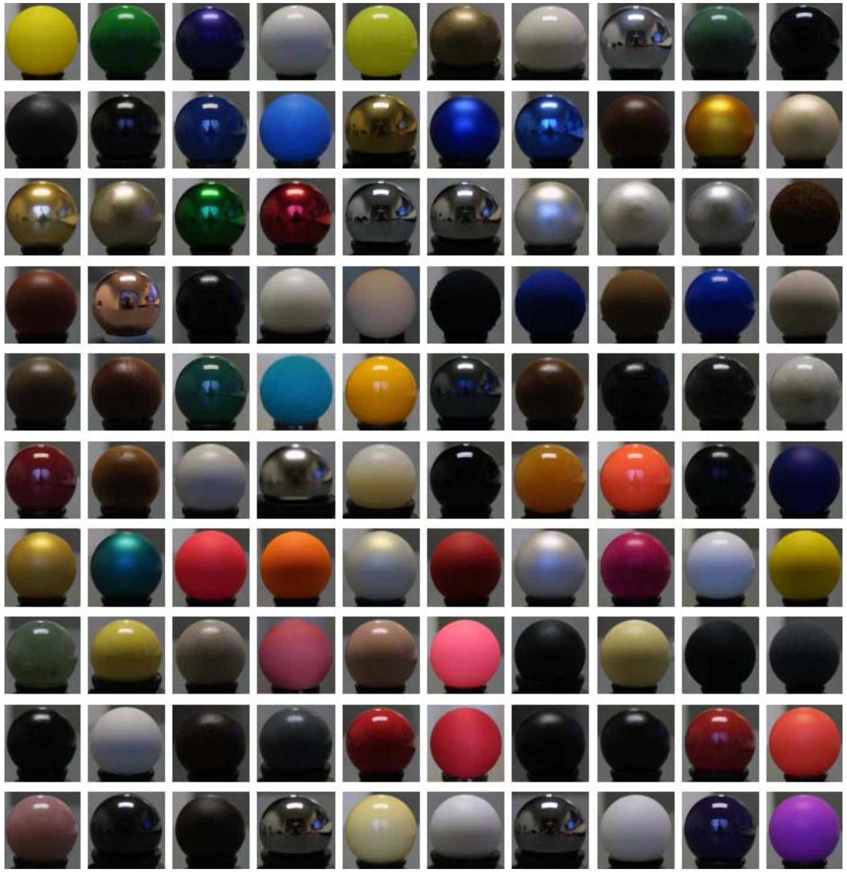


Yan et al. –Rendering Specular Microgeometry with Wave Optics, SIGGRAPH 2018

BRDF Acquisition



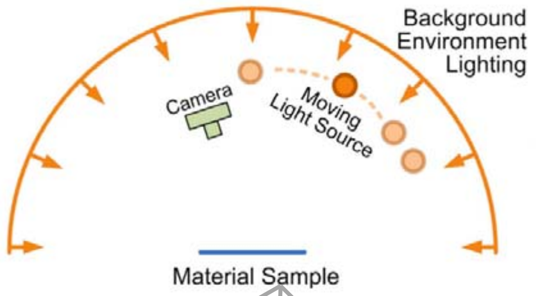
Measured BRDF

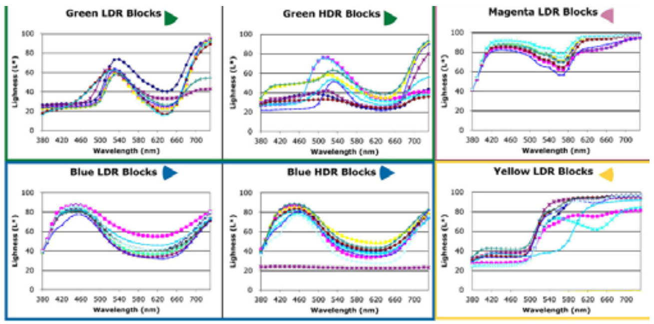


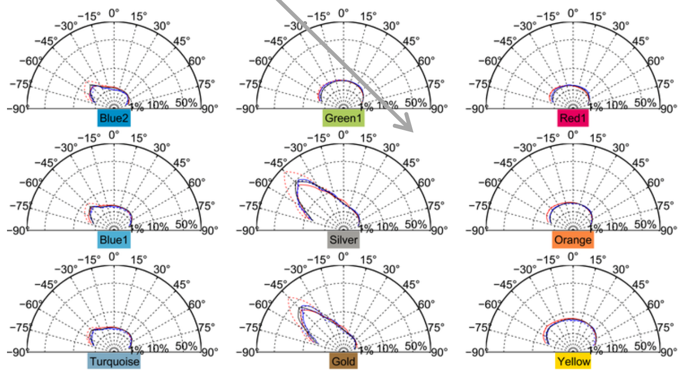
MERL BRDFs

UTIA BRDFs

Measured BRDF



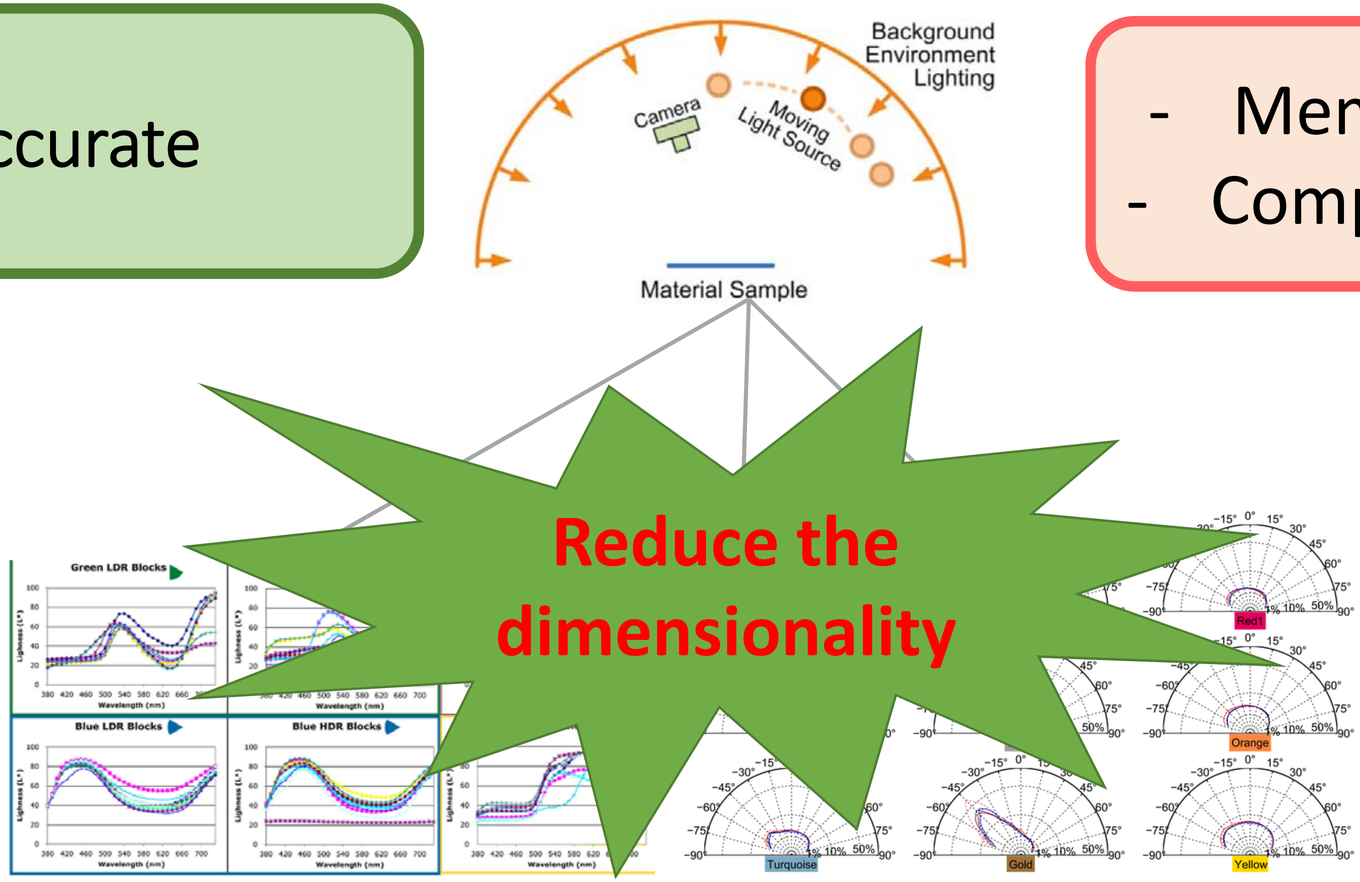




Measured BRDF

+ Accurate

- Memory footprint
- Computational cost



Reduce the dimensionality

Related Work

A data-driven reflectance model
[Matusik 2003]

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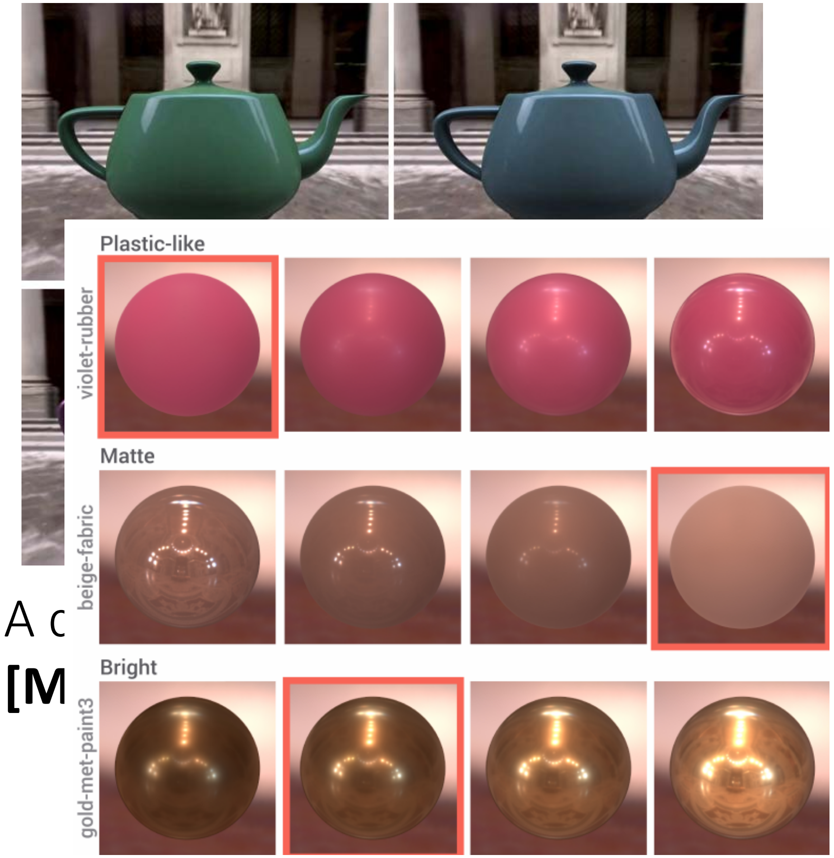
A data-driven reflectance model
[Matusik 2003]

On Optimal, Minimal BRDF Sampling
for Reflectance Acquisition
[Nielsen 2015](IPCA)

Related Work



A c

[M

An intuitive control space for material appearance

[Serrano et.al 2016]

On Optimal, Minimal BRDF Sampling for Reflectance Acquisition

[Nielsen 2015](IPCA)

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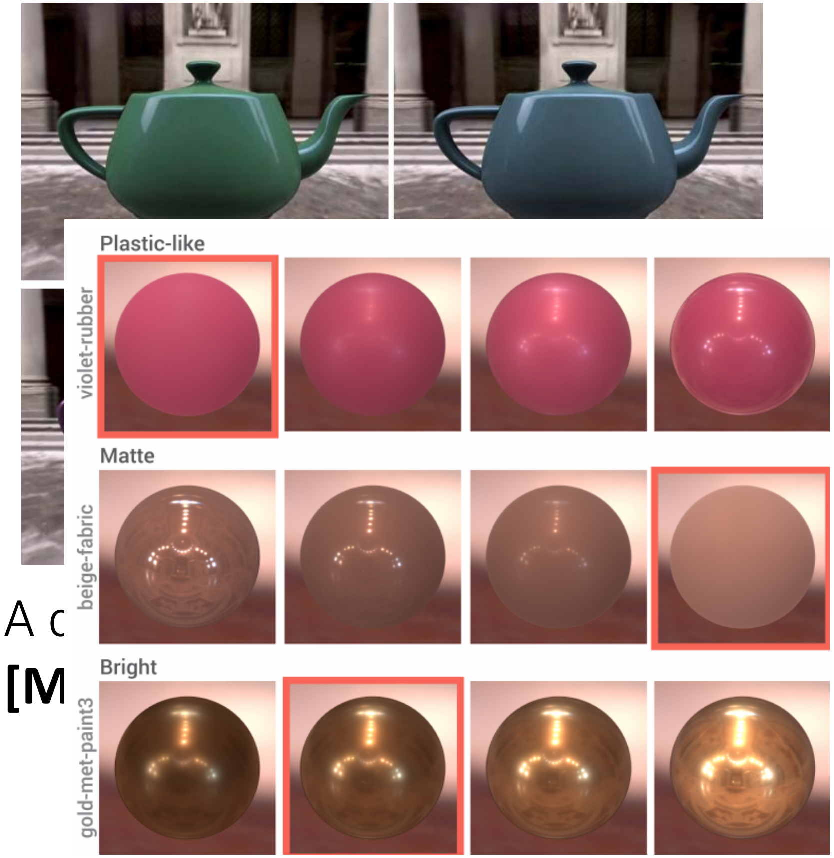

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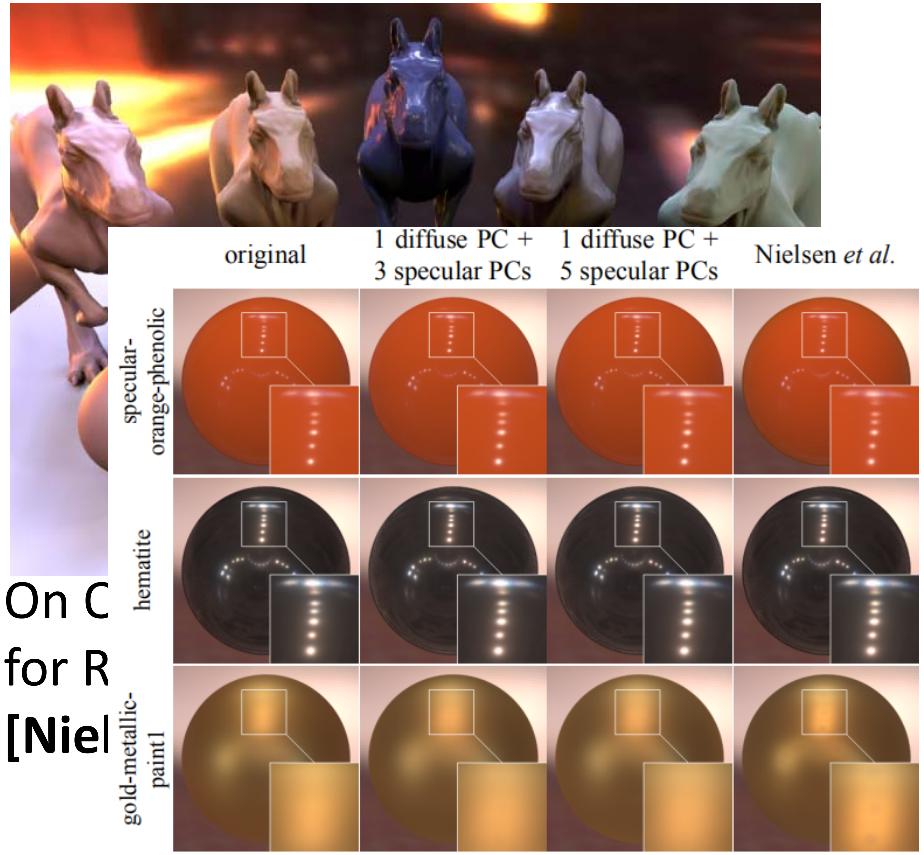
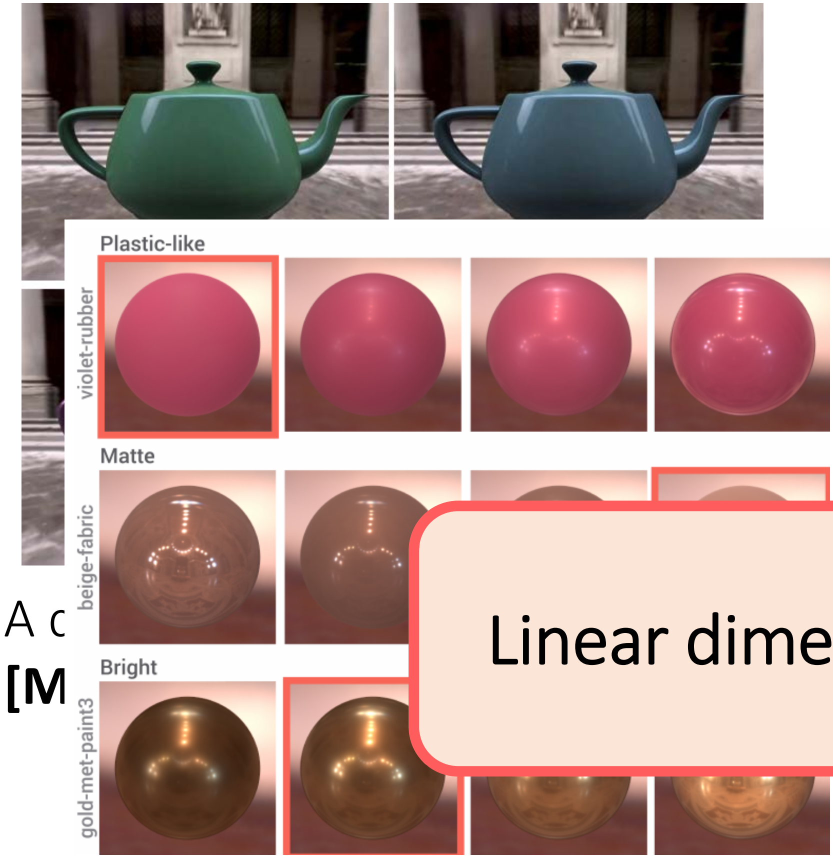


On C
for R
[Niel

Connecting measured brdfs to analytic brdfs by data-driven diffuse-specular separation.
[Sun et.al 2018]

Related Work



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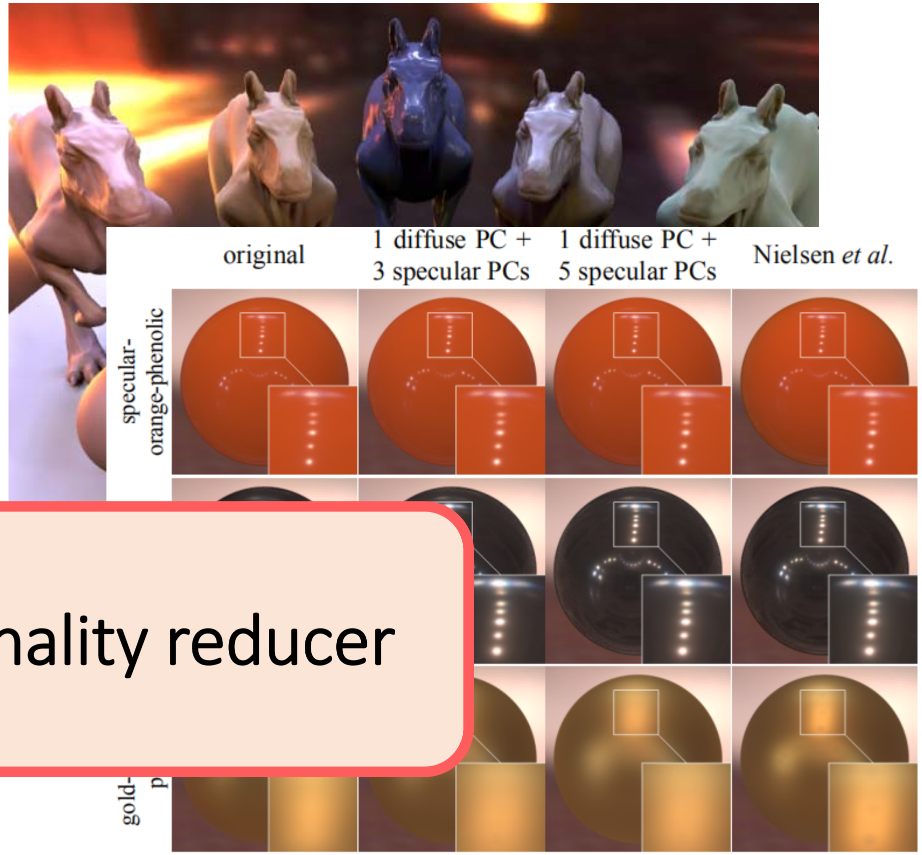
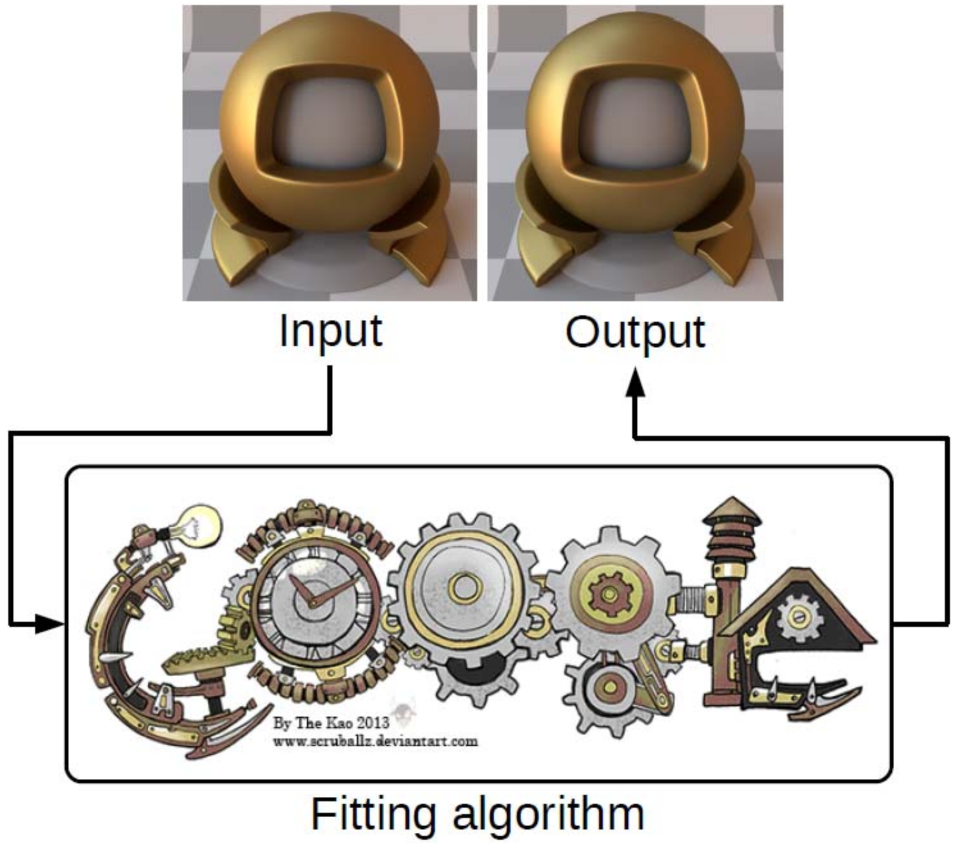


Connecting measured brdfs to analytic brdfs by data-driven diffuse-specular separation.
[Sun et.al 2018]

Linear dimensionality reducer

Related Work

Fitting measured BRDF to analytic models



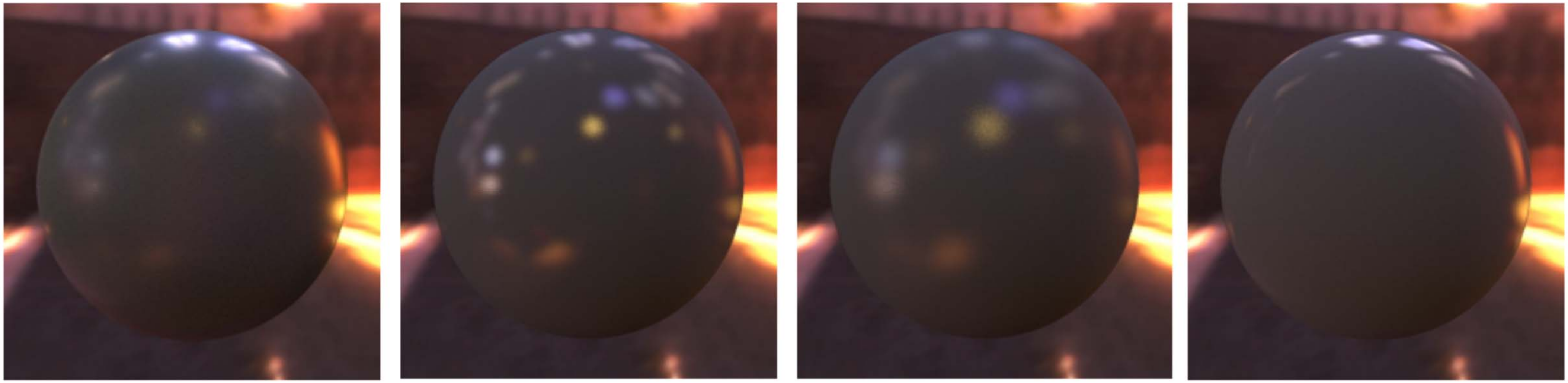
Related Work

Fitting measured BRDF to analytic models

[Ngan 2005] Experimental Analysis of BRDF Models

Related Work

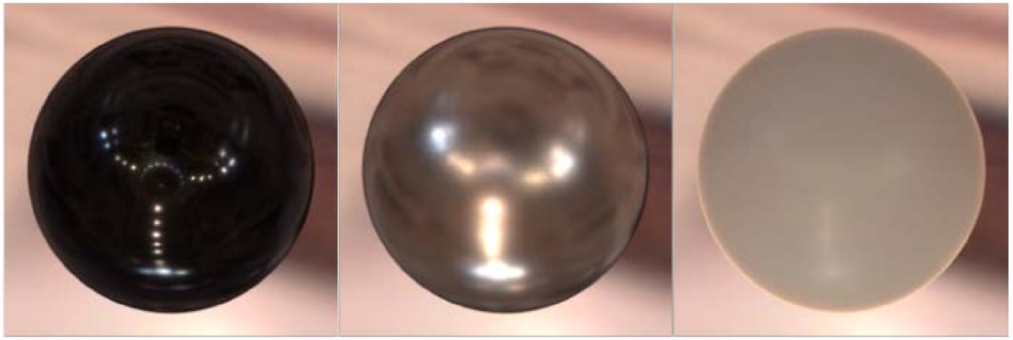
Measured | Ward | Blinn-Phong | Lafortune



- The fitting process is time-consuming and unstable.
    - For some materials, they are not accurate.

Our Approach

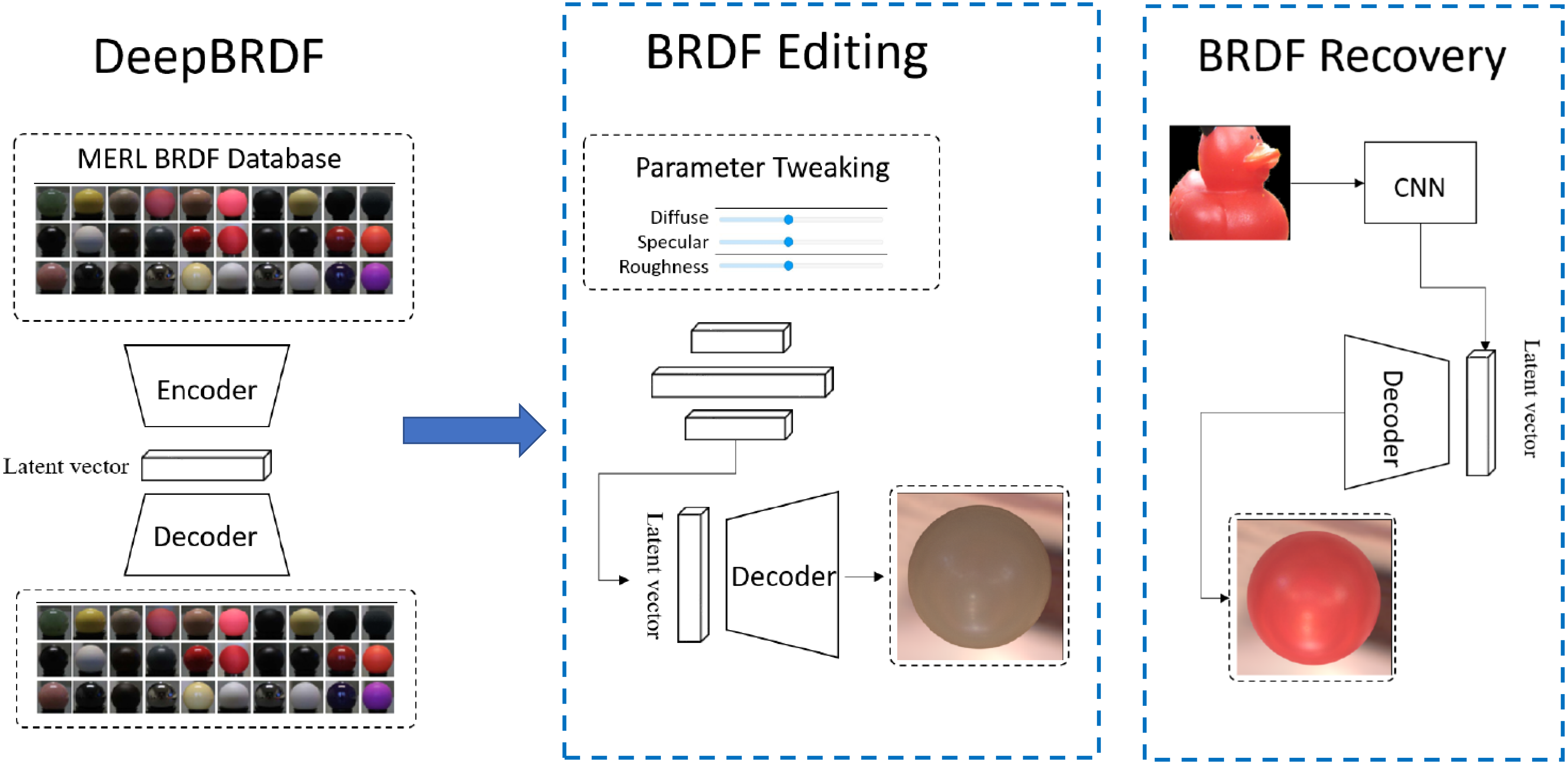
- Deep learning based dimensionality reducer to explore a nonlinear low-dimensional manifold for measure BRDFs



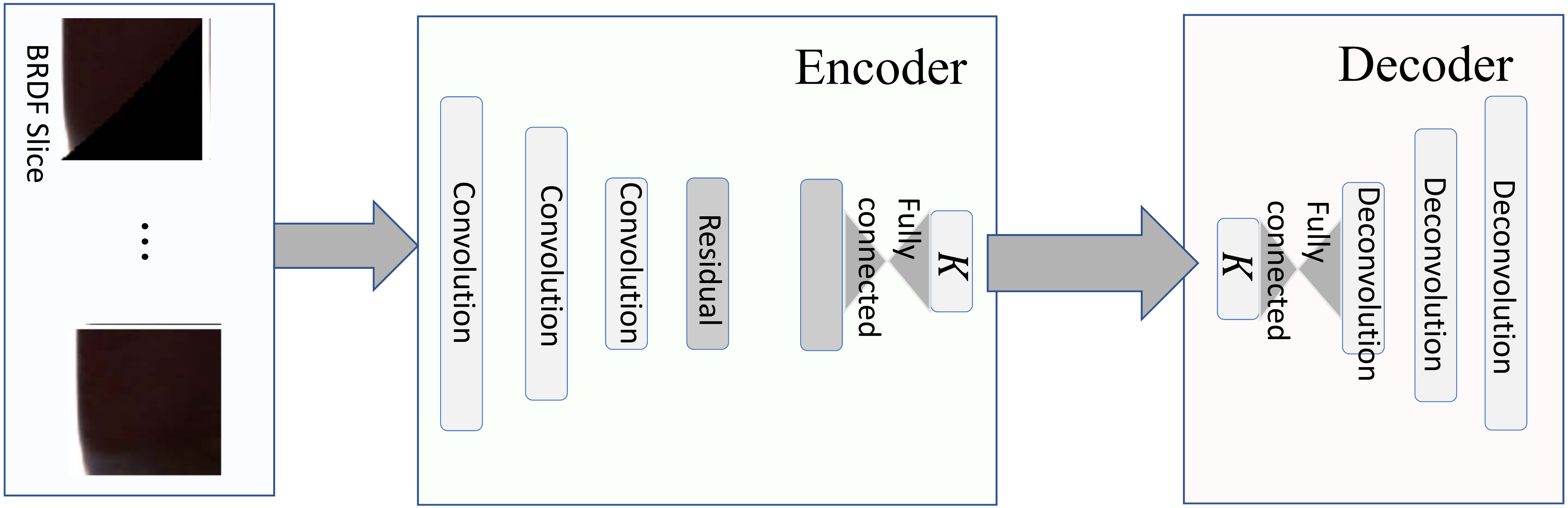
Original BRDF

DeepBRDF

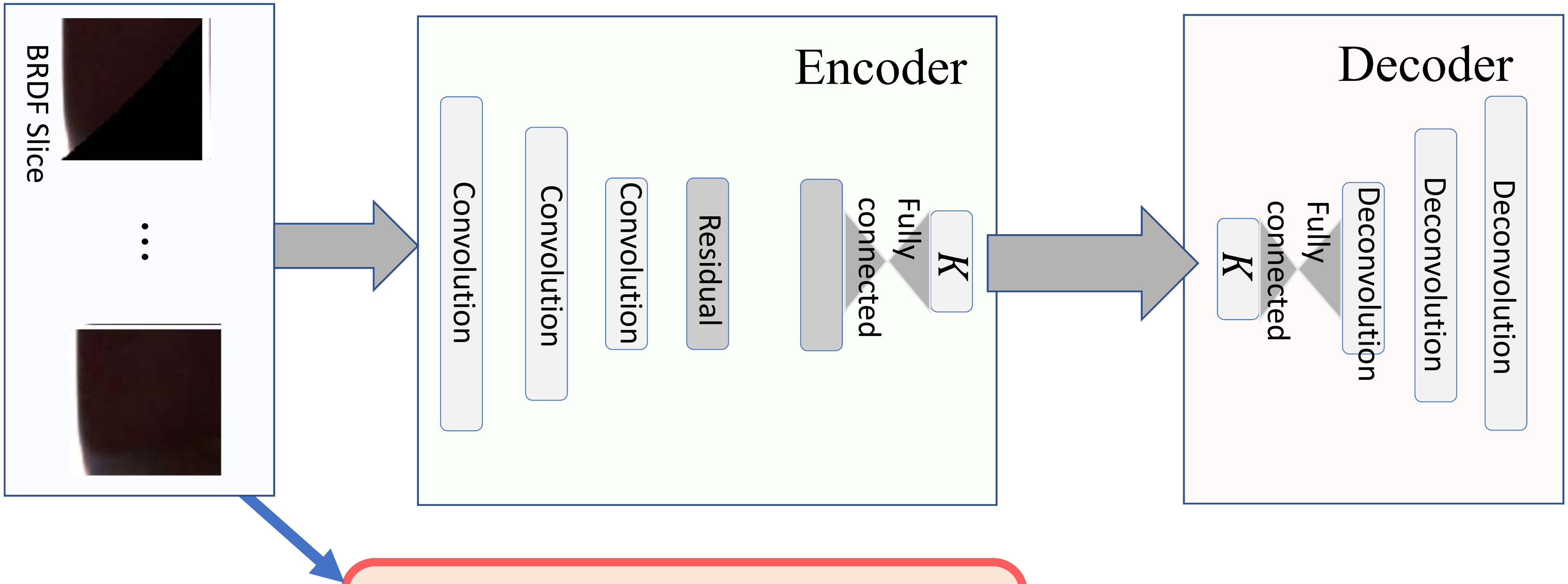
Basic Idea


DeepBRDF
MERL BRDF Database
Encoder
Latent vector
Decoder
BRDF Editing
Parameter Tweaking
Diffuse
Specular
Roughness
Latent vector
Decoder
BRDF Recovery
CNN
Decoder
Latent vector

Network Architecture

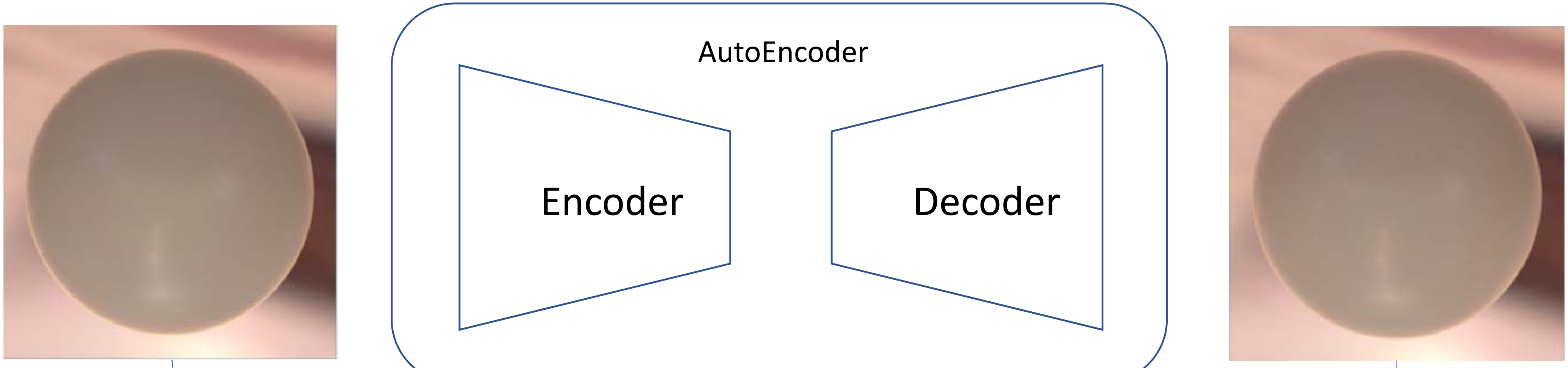


Network Architecture



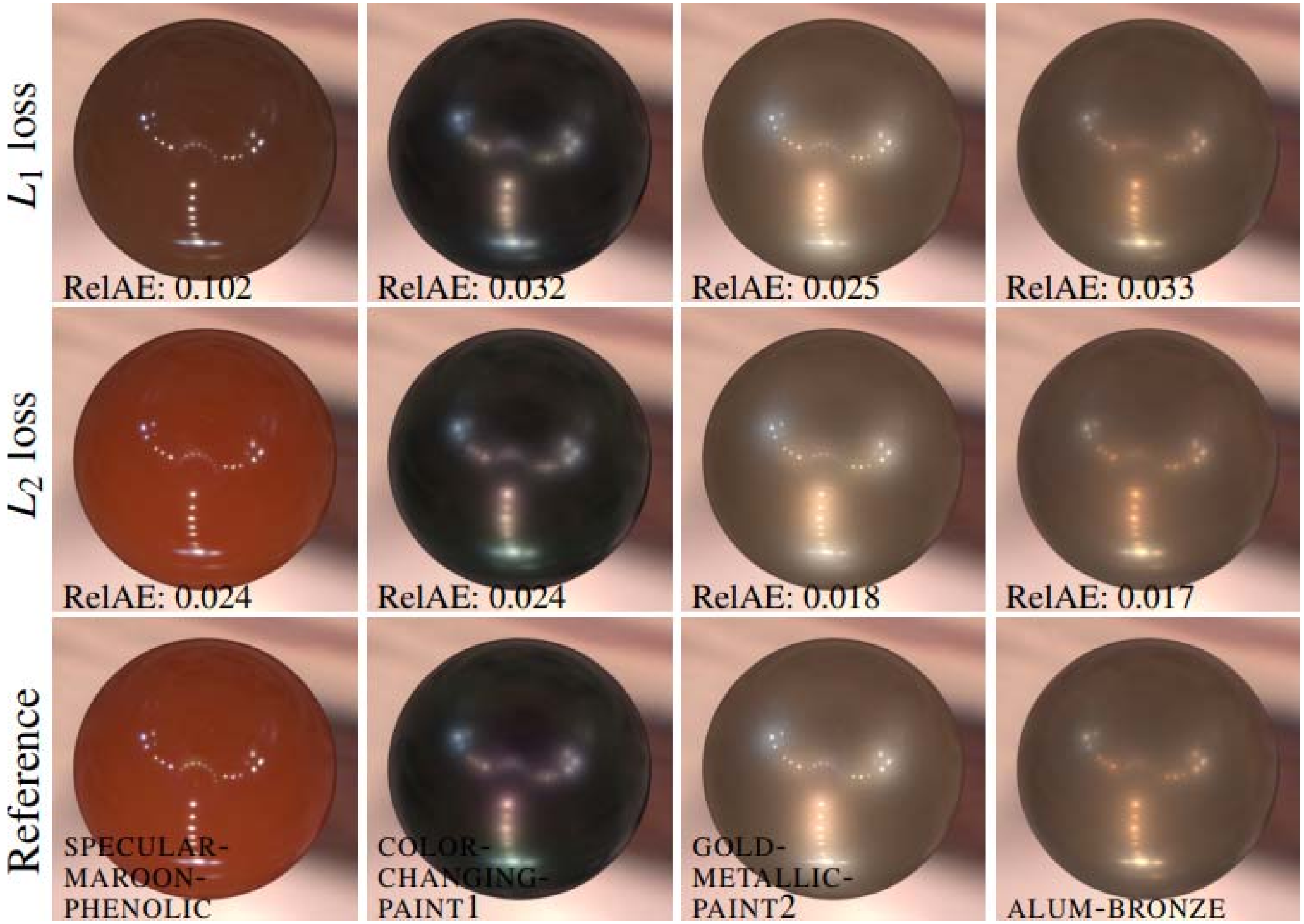
$$\rho = \ln\left(\frac{\rho + \epsilon}{\rho_{ref} + \epsilon} + 1\right)$$

Loss Function

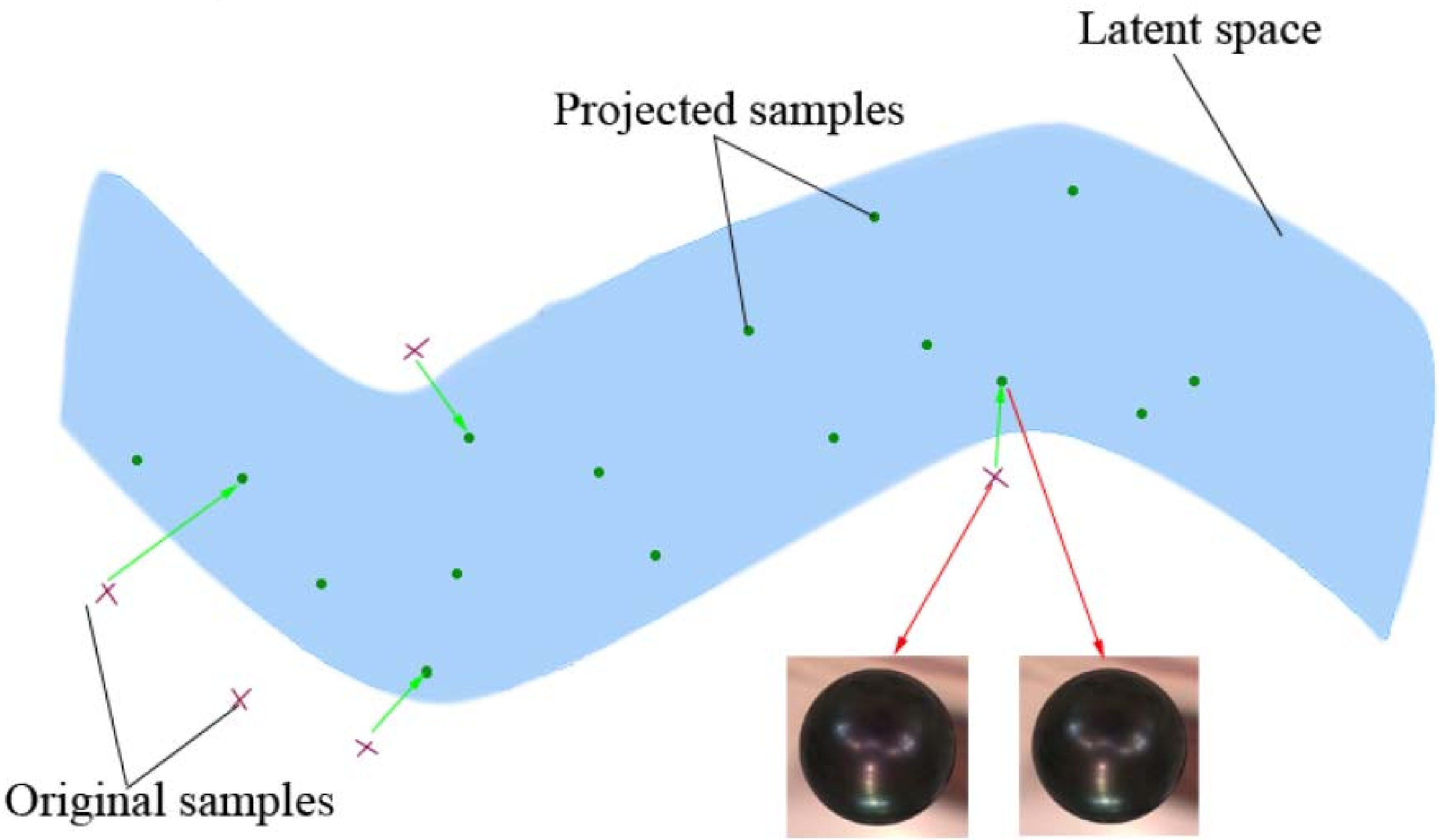


$$\mathcal{L} = \sum_{\mathbf{X} \in \mathcal{D}_{\text{train}}} \| mask(g_\theta(f_\theta(\mathbf{X}))) - mask(\mathbf{X}) \|$$

Loss Function



Geometric Interpretation



Quality Analysis

- Visual quality comparisons against PCA and improved PCA (IPCA)
- Quantitative evaluation in terms of RelAE is provided for each reconstructed result

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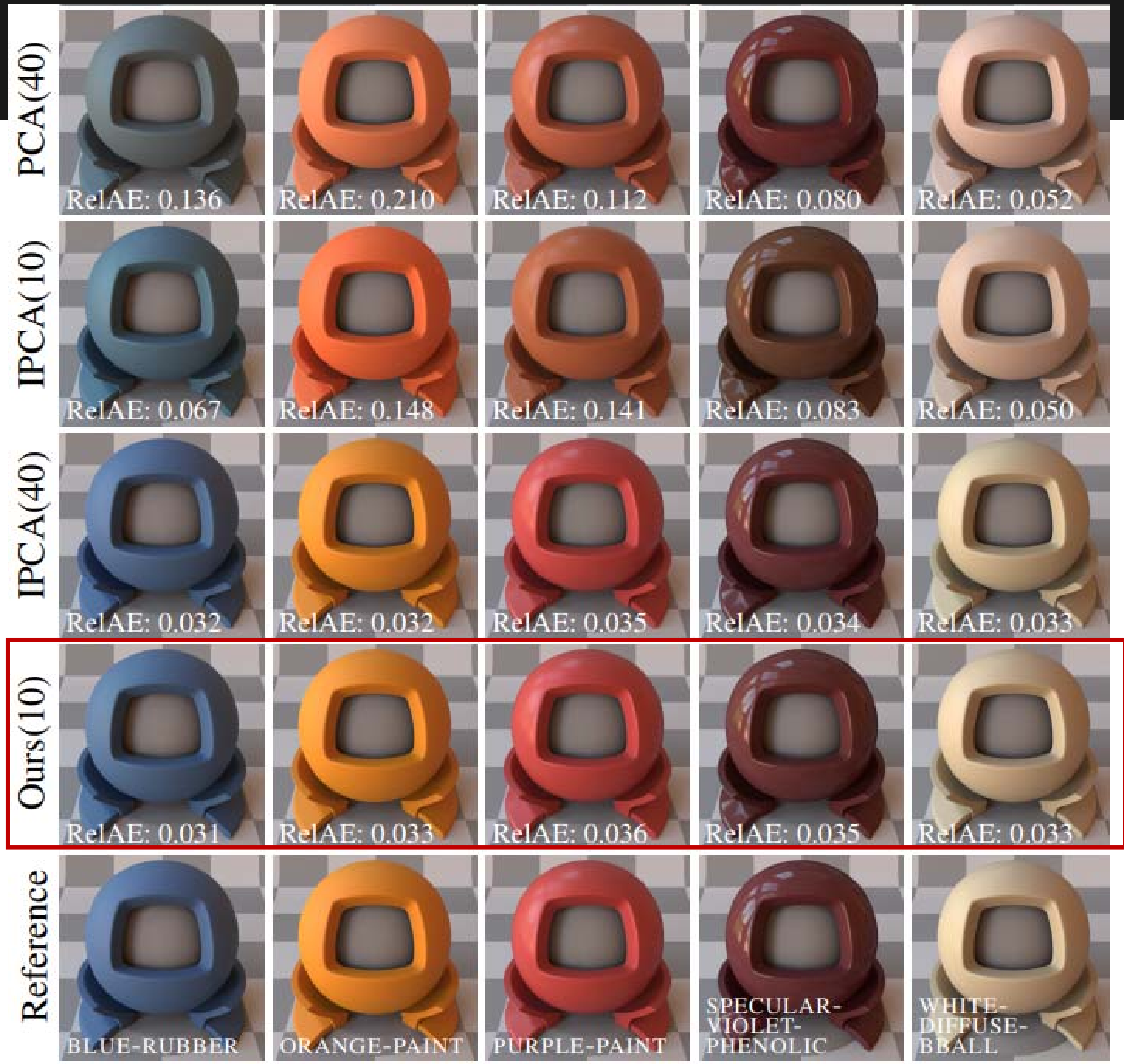
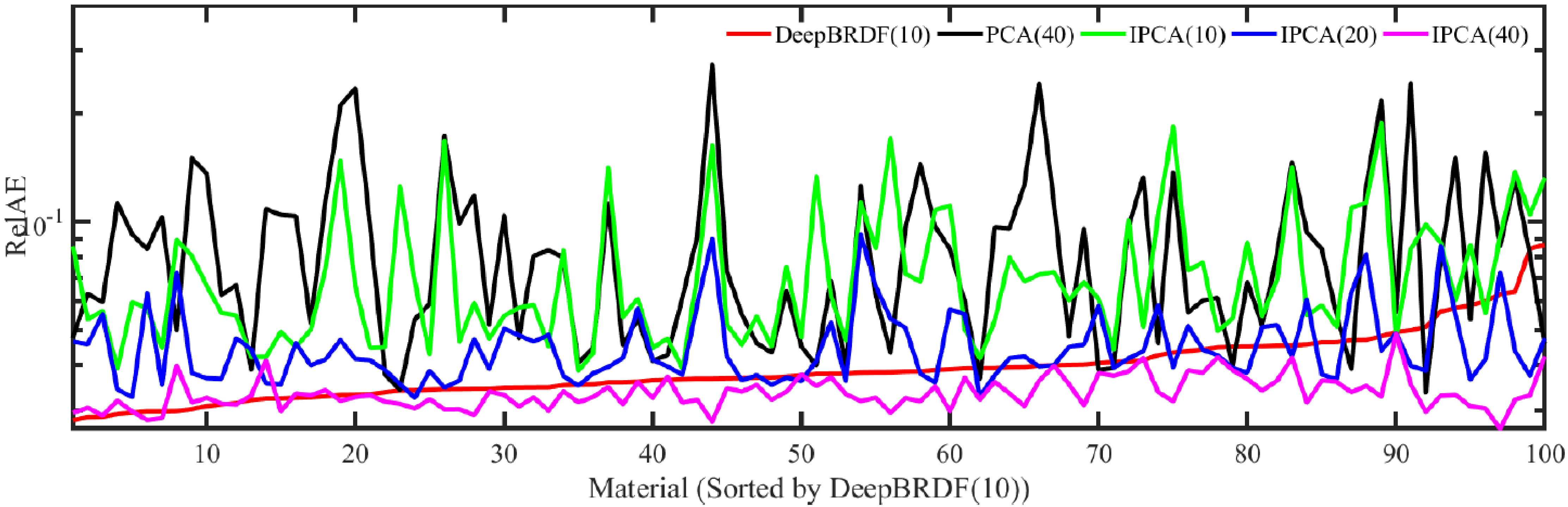
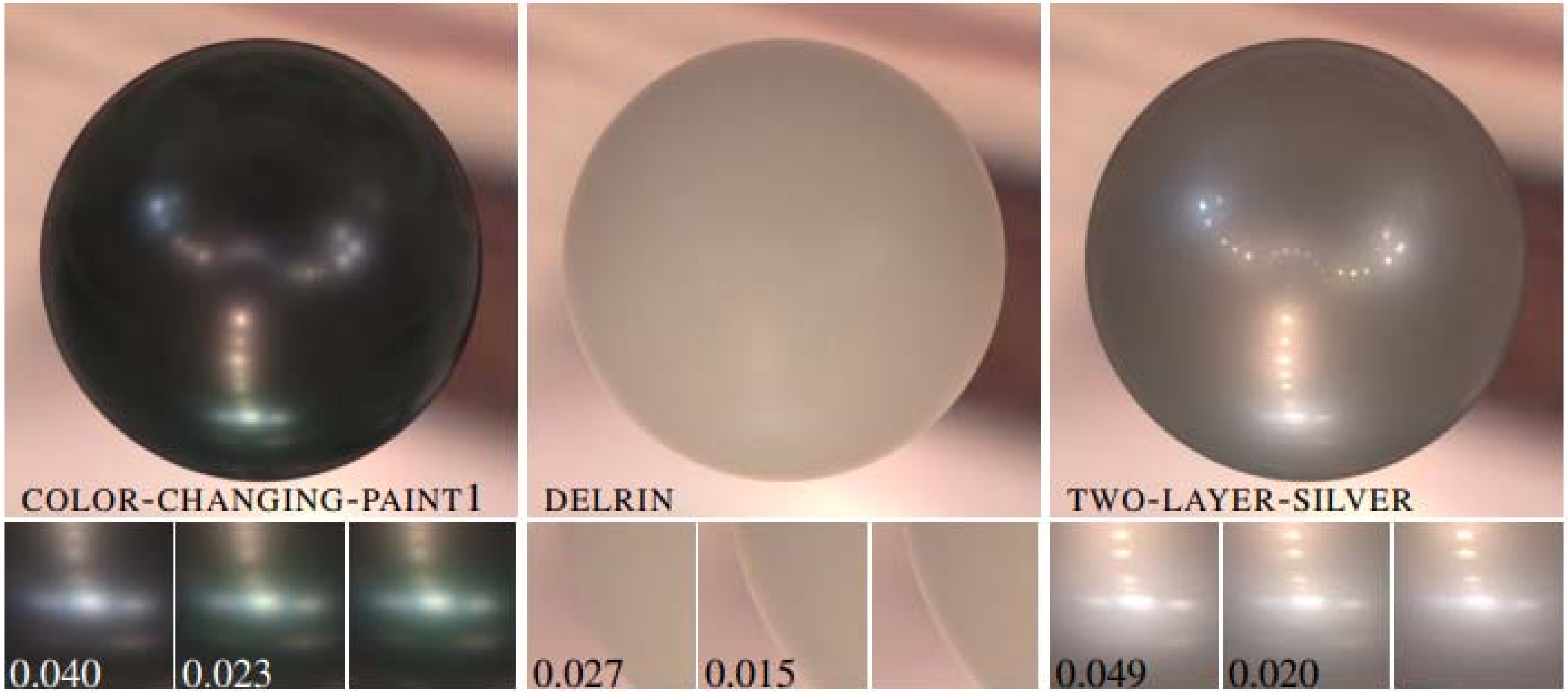


Quality Analysis



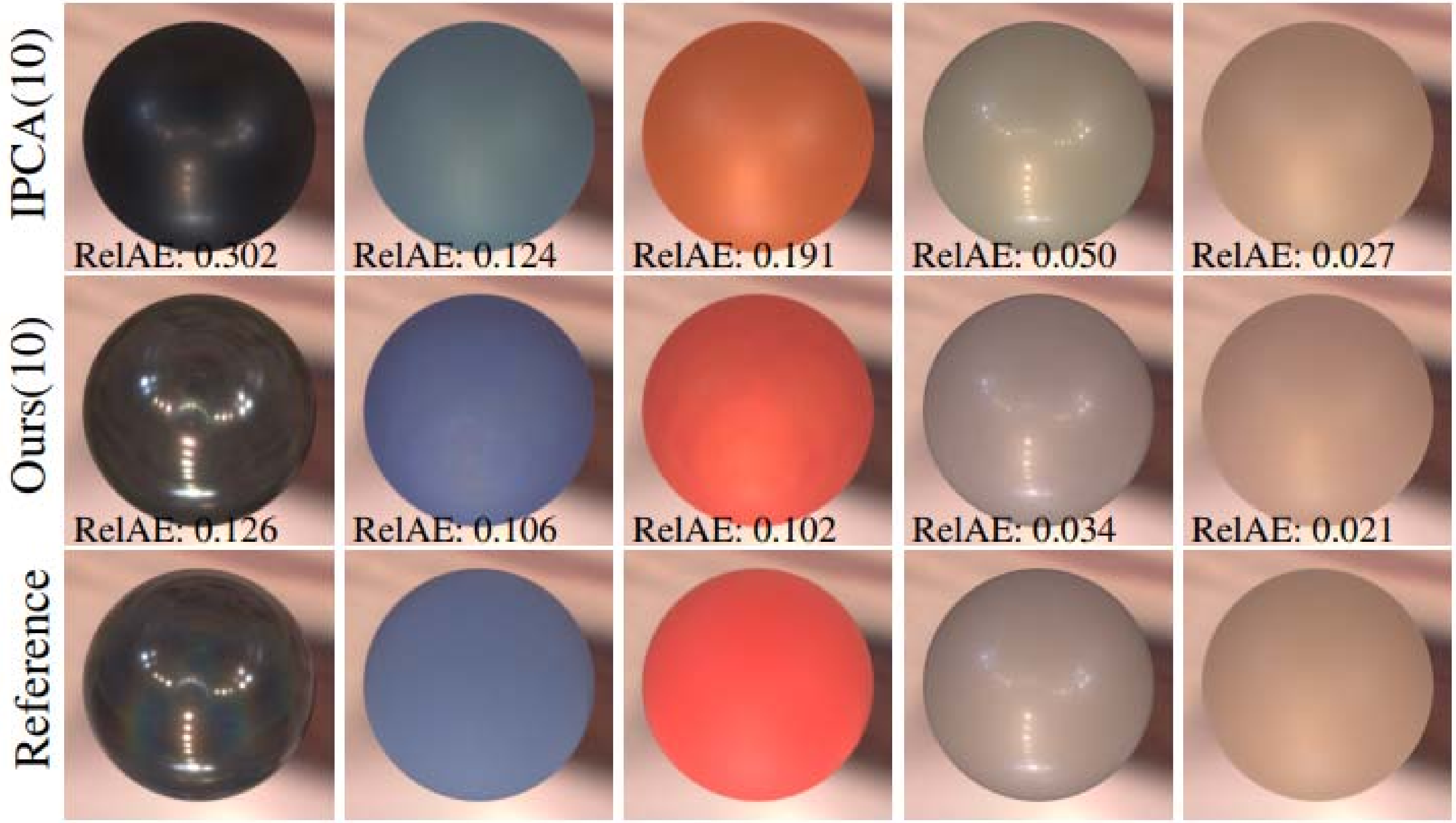
- Reconstruction error comparison of our DeepBRDF against PCA and IPCA with varying dimensions.

Quality Analysis



- From left to right in each group of closeups, we compare the method of Sun et al. [SJR18], ours and the reference, with corresponding RelAE.

Quality Analysis



- Evaluation on other BRDF data (not in MERL dataset)

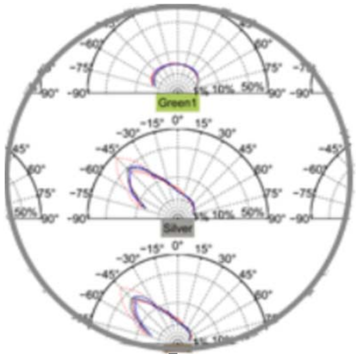
Applications

- Measured BRDF editing

- Single Image BRDF Recovery

Measured BRDF Editing

Measured BRDF



Low-dim. representation

DeepBRDF (***Y***)
(10D Latent Vector)

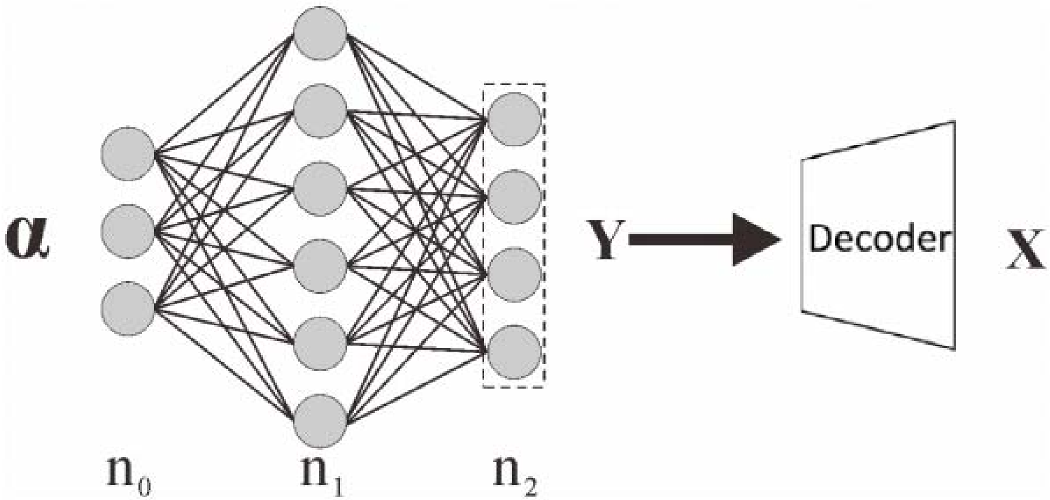
φ

Perceptual appearance

Attributes

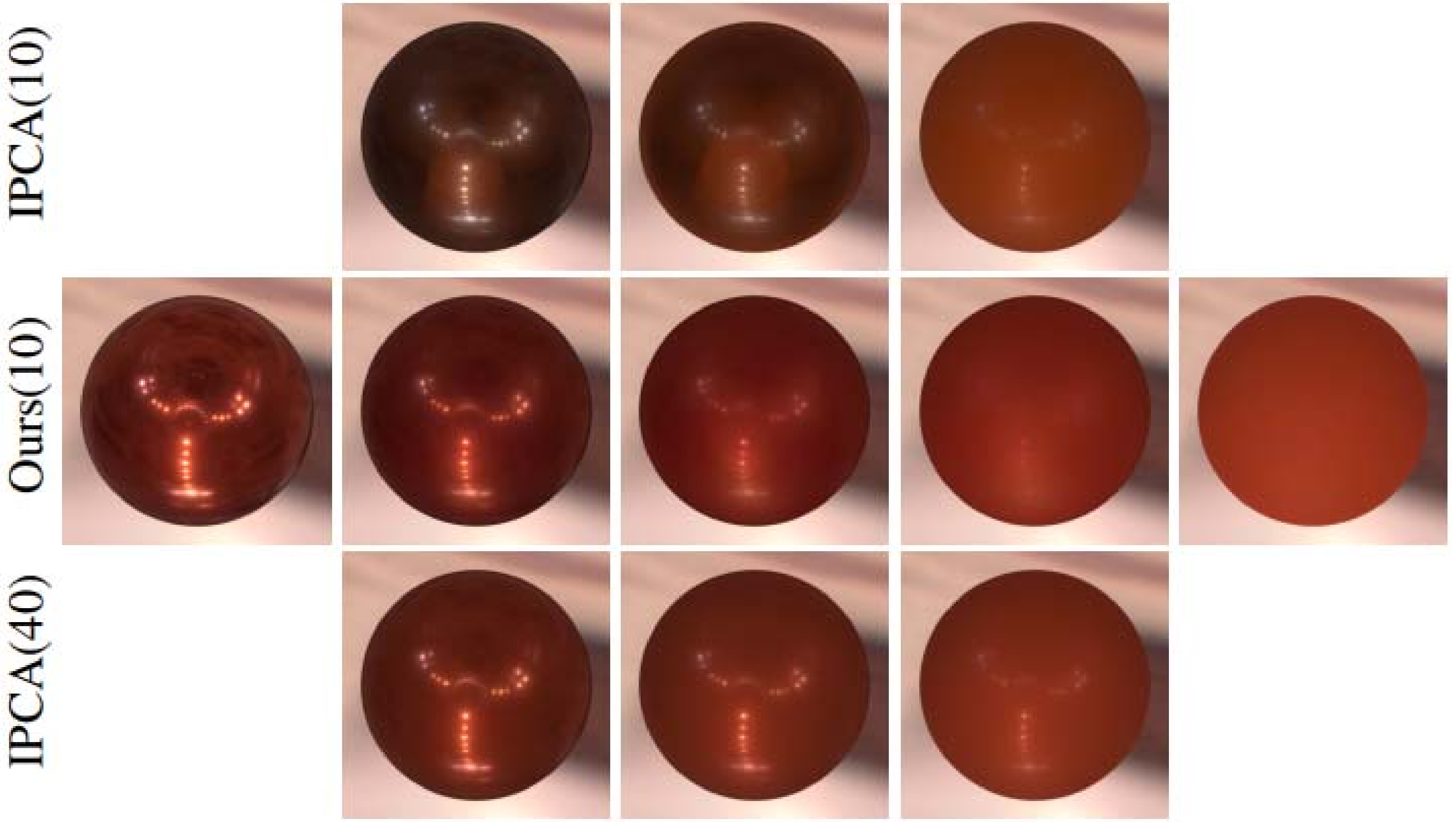
Diffuse albedo(α_d)
Specular albedo(α_s)
roughness(g)

Measured BRDF Editing



Train a Back Propagation (BP) regression network to establish the relationship between $\boldsymbol{Y}$ (latent vector) and $\boldsymbol{\alpha}(\boldsymbol{\alpha_s} \in \mathbb{R}^{\mathbf{3}}, \boldsymbol{\alpha_d} \in \mathbb{R}^{\mathbf{3}}, \boldsymbol{g} \in \mathbb{R})$

Measured BRDF Editing



- Linear interpolation between *RED-METALLIC-PAINT* and *RED-FABRIC* using IPCA and our DeepBRDF, respectively

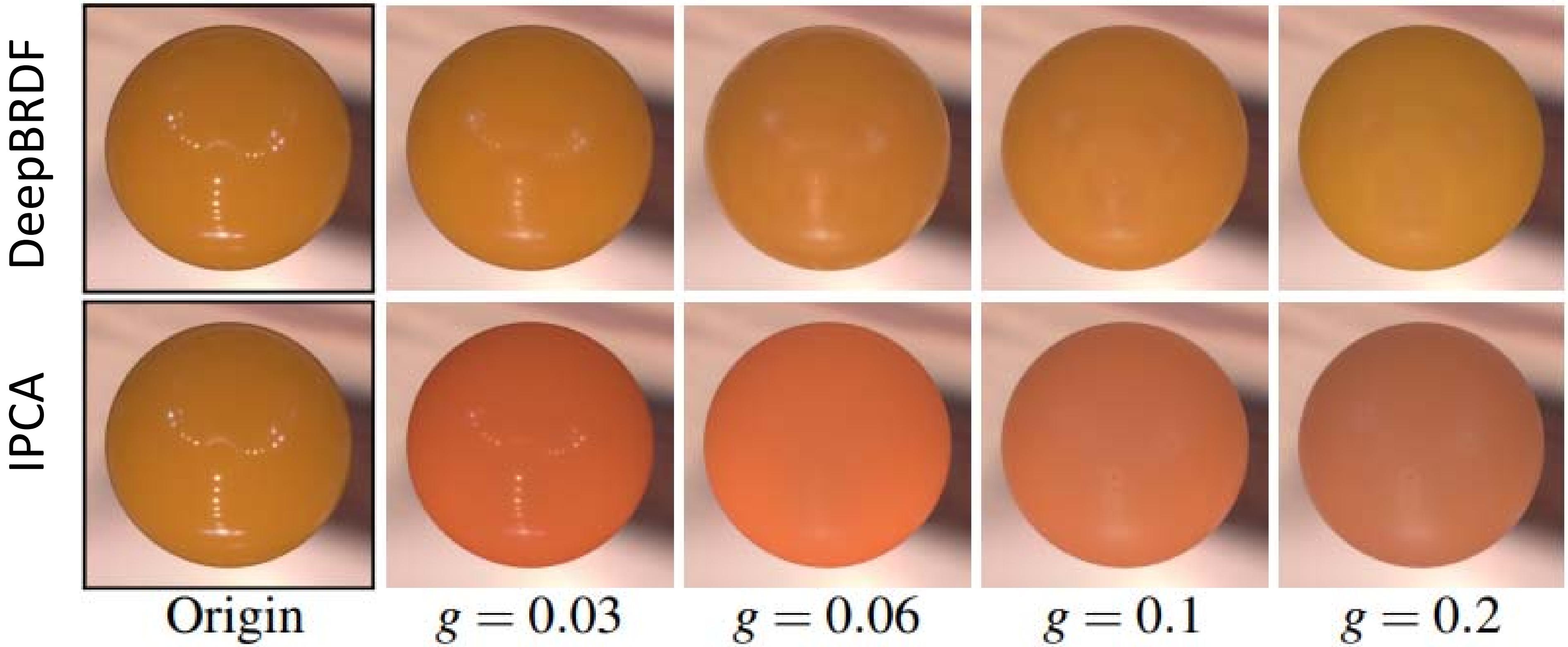
Measured BRDF Editing

- Editing diffuse albedo

Measured BRDF Editing

- Editing the roughness of *RED-PLASTIC*

Measured BRDF Editing

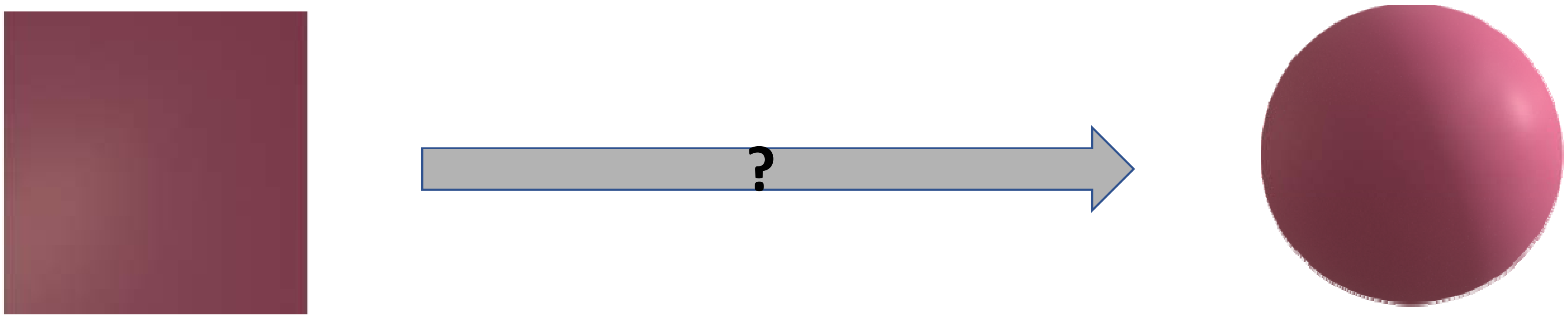


- Editing the roughness of *SPECULAR-YELLOWPHENOLIC* with IPCA-based representation (bottom row) and DeepBRDF-based representation (top row)

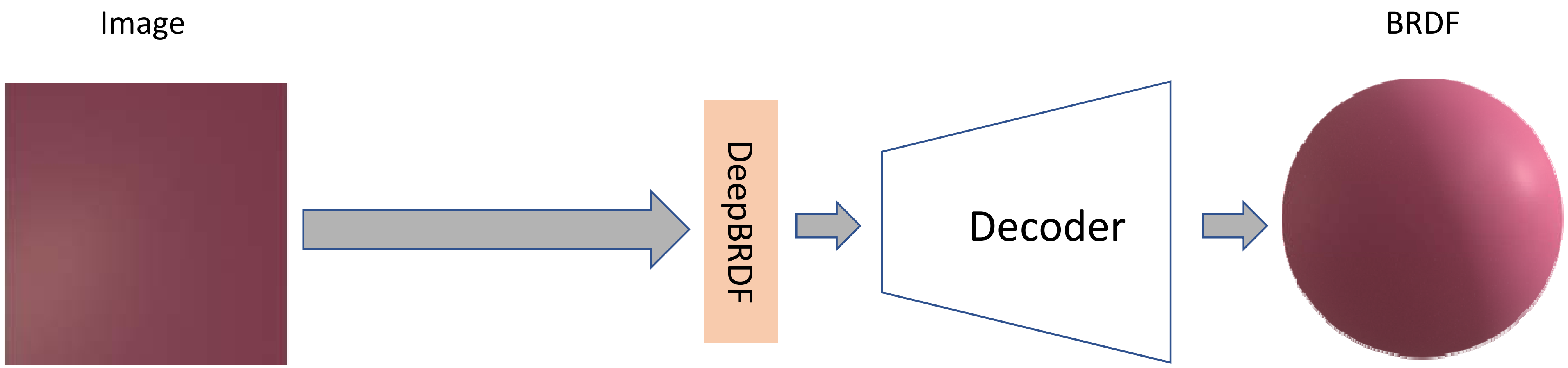
Single Image BRDF Recovery

Image

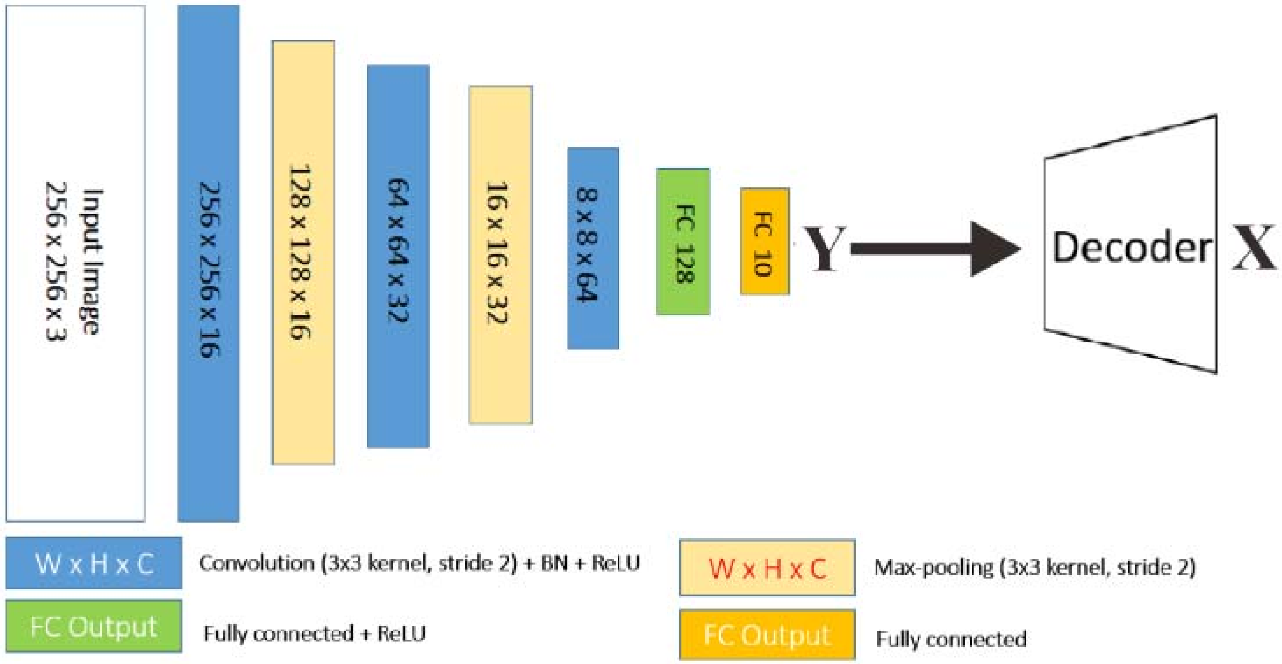
BRDF



Single Image BRDF Recovery



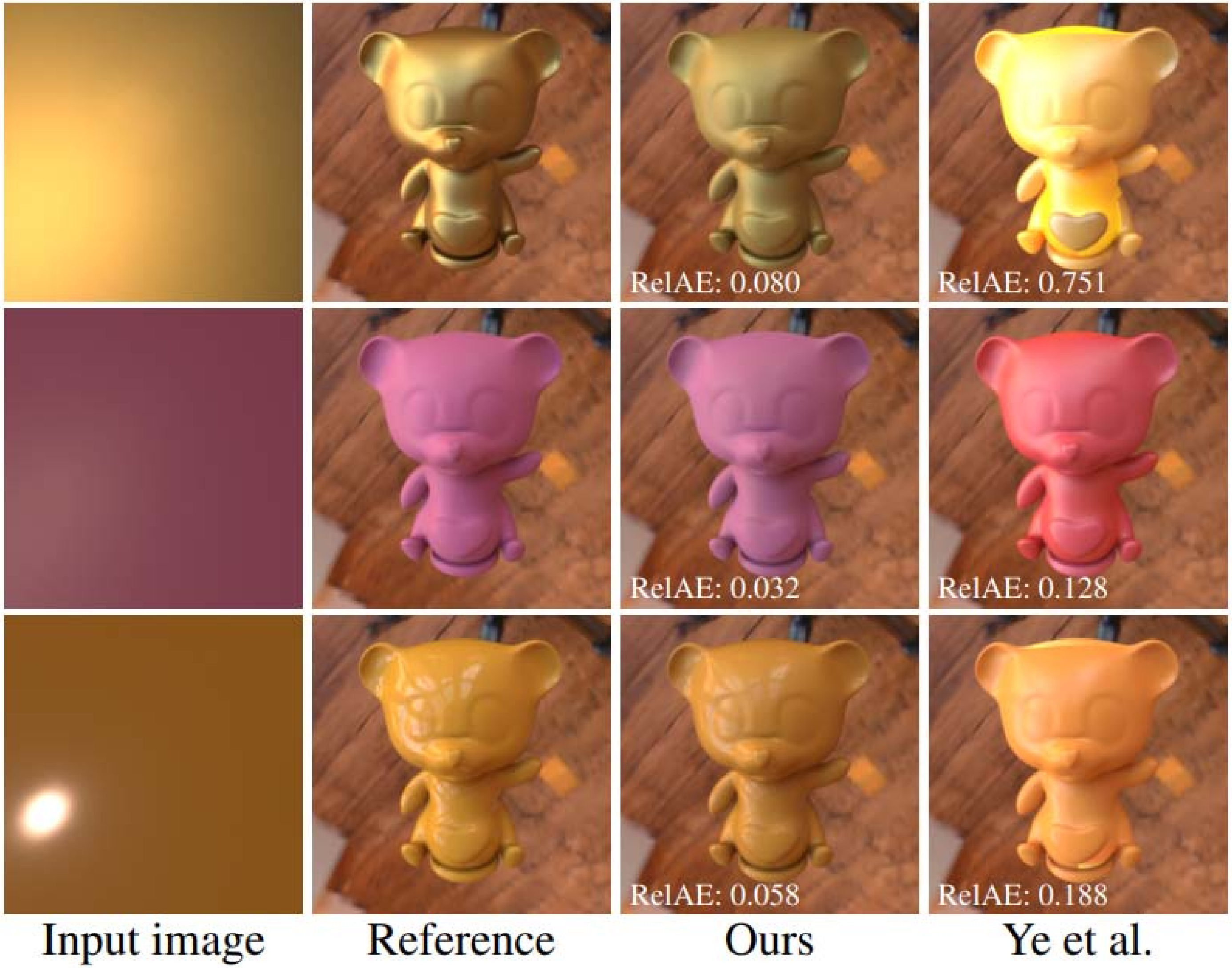
Single Image BRDF Recovery



- A new CNN is trained to map the input image to the latent space of DeepBRDF.

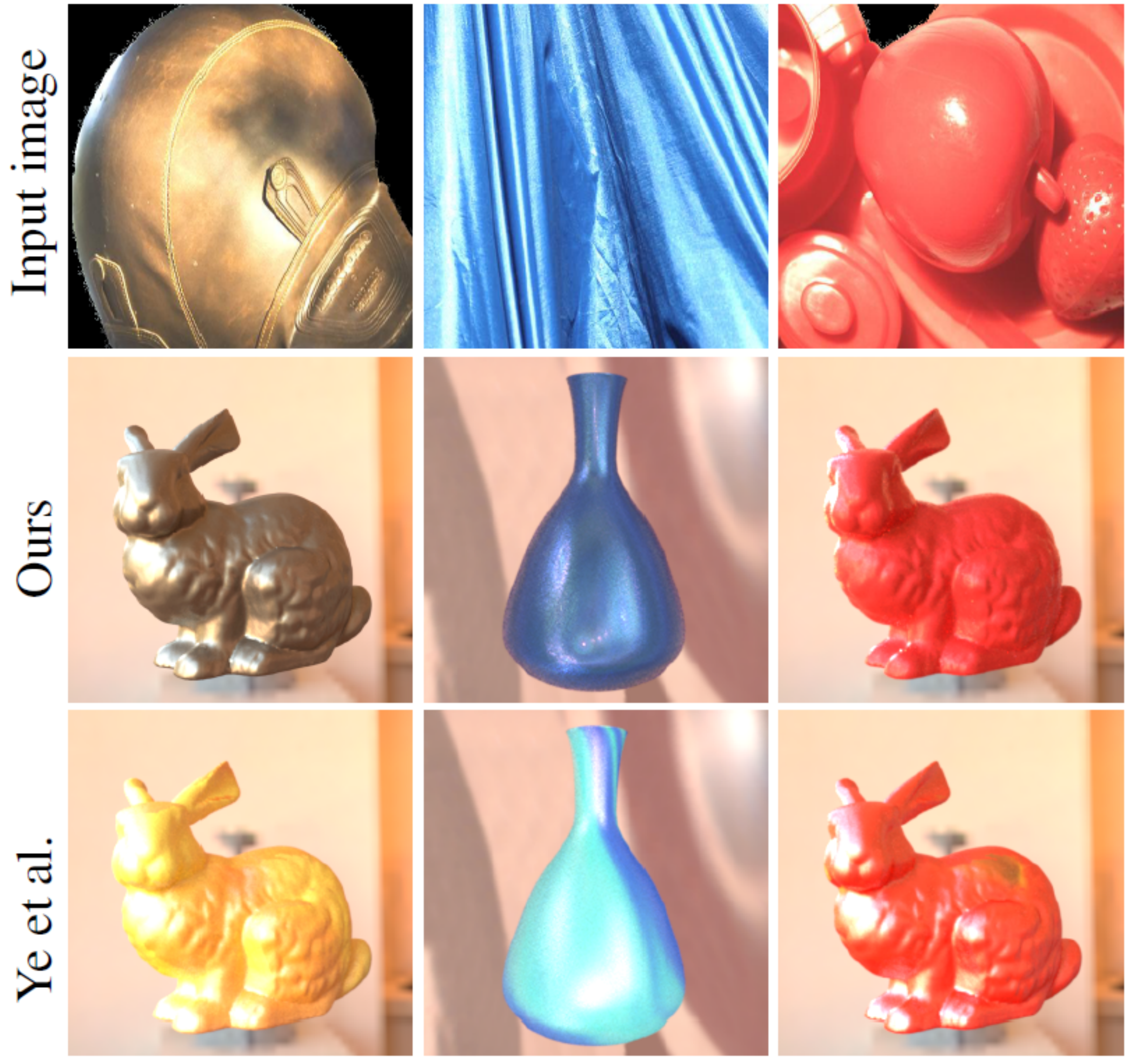
Single Image BRDF Recovery

- Comparison with the method of Ye et al. [YLD*18] in homogeneous BRDF recovery.



Single Image BRDF Recovery

- BRDF recovery results for real-world images.



Conclusion

- We have presented DeepBRDF, a deep-learning-based representation for Measured BRDF.
- We have apply the DeepBRDF to edit measured BRDFs.
- We have apply the DeepBRDF to the task of single image BRDF recovery.

Thank you!

Q&A