

Surface Flows for Image-based Shading Design: Supplemental material

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1 Derivation of Equation 8

We first provide a step-by-step derivation of Eq.8, omitted in the paper for brevity. We start by replacing $\partial_{\mathbf{x}}\mathcal{R}_{\mathbf{n}}$ in Eq.4, by the formulation given in Eq.6:

$$\begin{aligned}\partial_{\mathbf{x}}\rho_{\mathbf{z}} &= (\partial_{\mathbf{x}}\mathbf{p} \cdot \partial_{\mathbf{p}}\rho_{\mathbf{z}}) + (\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \times \mathcal{R}_{\mathbf{n}}\mathbf{v} \cdot \partial_{\nu}\rho_{\mathbf{z}}) \\ &= (\partial_{\mathbf{x}}\mathbf{p} \cdot \partial_{\mathbf{p}}\rho_{\mathbf{z}}) + (\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \cdot \mathcal{R}_{\mathbf{n}}\mathbf{v} \times \partial_{\nu}\rho_{\mathbf{z}}),\end{aligned}$$

where the second line is obtained by a re-ordering of the scalar triple product of the form: $(\mathbf{a} \times \mathbf{b}) \cdot \mathbf{c} = \mathbf{a} \cdot (\mathbf{b} \times \mathbf{c})$, with $\mathbf{a} = \partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n}$, $\mathbf{b} = \mathcal{R}_{\mathbf{n}}\mathbf{v}$ and $\mathbf{c} = \partial_{\nu}\rho_{\mathbf{z}}$. We proceed similarly for replacing $\partial_{\mathbf{x}}\mathcal{R}_{\mathbf{n}}^{-1}$ in Eq.5 by its formulation given in Eq.7:

$$\partial_{\mathbf{x}}L_i = (\partial_{\mathbf{x}}\mathbf{p} \cdot \partial_{\mathbf{p}}L_i) - (\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \cdot \mathcal{R}_{\mathbf{n}}\ell \times \partial_1L_i).$$

Now we insert both formula in Eq.3, yielding:

$$\begin{aligned}\partial_{\mathbf{x}}L_r &= \int_{\Omega_{\mathbf{z}}^+} (\partial_{\mathbf{x}}\mathbf{p} \cdot \partial_{\mathbf{p}}\rho_{\mathbf{z}})L_i + (\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \cdot \mathcal{R}_{\mathbf{n}}\mathbf{v} \times \partial_{\nu}\rho_{\mathbf{z}})L_i dF \\ &+ \int_{\Omega_{\mathbf{z}}^+} (\partial_{\mathbf{x}}\mathbf{p} \cdot \partial_{\mathbf{p}}L_i)\rho_{\mathbf{z}} - (\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \cdot \mathcal{R}_{\mathbf{n}}\ell \times \partial_1L_i)\rho_{\mathbf{z}} dF.\end{aligned}$$

Since we are interested in surface shape variations $\partial_{\mathbf{x}}\mathbf{p}$ and $\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n}$, we re-organize the equation to factor these terms out:

$$\begin{aligned}\partial_{\mathbf{x}}L_r &= \left(\partial_{\mathbf{x}}\mathbf{p} \cdot \int_{\Omega_{\mathbf{z}}^+} \partial_{\mathbf{p}}\rho_{\mathbf{z}} L_i + \partial_{\mathbf{p}}L_i \rho_{\mathbf{z}} dF \right) \\ &+ \left(\partial_{\mathbf{x}}\mathbf{n} \times \mathbf{n} \cdot \int_{\Omega_{\mathbf{z}}^+} (\mathcal{R}_{\mathbf{n}}\mathbf{v} \times \partial_{\nu}\rho_{\mathbf{z}})L_i - (\mathcal{R}_{\mathbf{n}}\ell \times \partial_1L_i)\rho_{\mathbf{z}} dF \right)\end{aligned}$$

which corresponds to Eq.8 where Eq.9 and 10 have been explicitly incorporated.

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2 Comparison with environment mapping

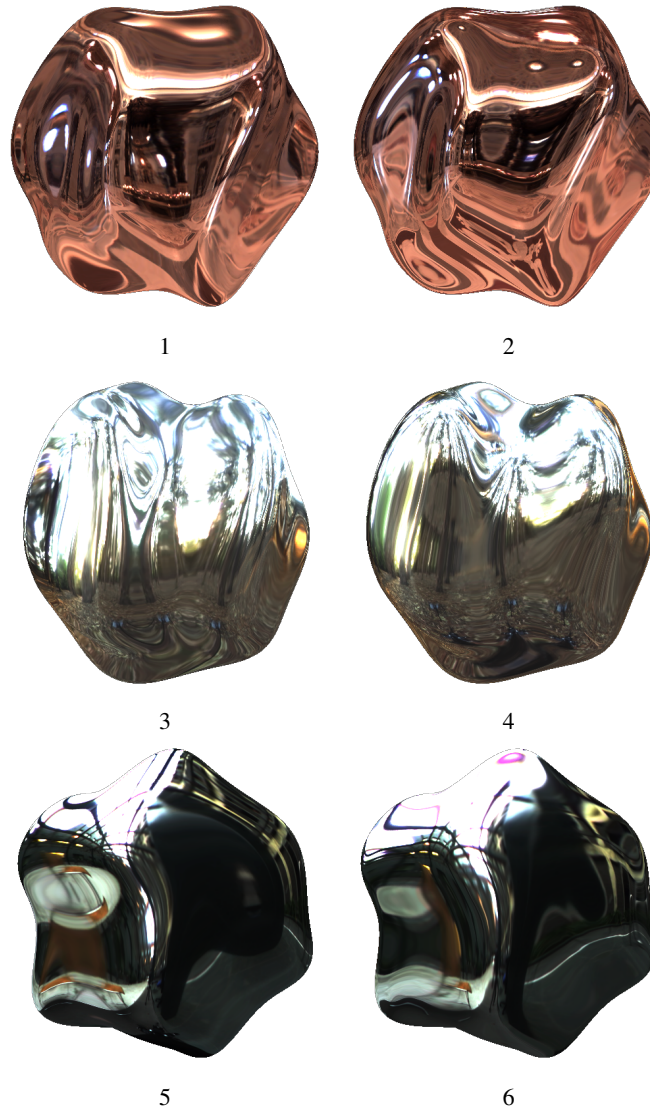


Figure 1: Which one is an environment mapping? Which one corresponds to our technique? See bottom of page for answer.

We tried to reproduce the distortions obtained via classic environment mappings, using original latitude-longitude maps as input images and one anchor point per rendering. For this purpose, we positioned the anchor points and modified the parameters α and β so that the results appeared to be as close as possible to the original renderings. As shown in Figure 1, variations created with our (2^{nd} order) operator are similar and it is then difficult to see which of the images correspond to the true environment mappings.

Answer: 3D rendering \rightarrow 2, 4, 5 / Image deformation \rightarrow 1, 3, 6.

3 Detailed results

Image-based shading.

Figure 2 The steps to render the RGBN image [Toler-Franklin et al. 07] are shown in Figure 2. They are all done in a single node in our framework. This result is obtained using the image tool and a single anchor point:

1. (a,b,c) Set α to 0.9 to deform the input image (a simple gradient) and produce two diffuse renderings: a bright one and dark one.
2. (d) Mix the renderings using the Fresnel coefficient to obtain the final result.



Figure 2: RGBN image. This result is obtained using a single gradient image as input and one anchor point. In the top row (a,b,c), the gradient is distorted (by increasing α) until the shape appears to have a 'diffuse-like' material. The same operation is done in the second row (a,b,c), except that the intensity of the input image was decreased. The final result (d) combines the images obtained in (c) using the Fresnel coefficient. All these operations are done in a single node in our system.

Figure 3 The stylized cat shows how to easily draw highlights on top of a normal map taken from [Johnston 02]:

1. (b) Deform a single smooth blob with the image tool and one anchor point ($\alpha = 0.3$) to obtain the diffuse layer, starting from the input normal map (a).
2. (c) Draw highlights using the brush tool ($\alpha = 0.6$).
3. (e) Multiply the produced shading with the given reflectance map (d) to obtain the result.

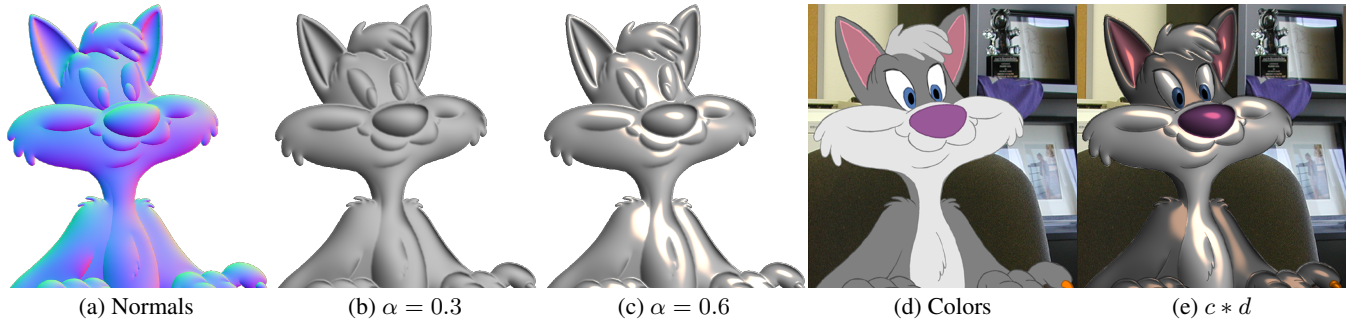


Figure 3: Lumo. The normal map (a) is used to distort a single blurry blob and create a Lambertian surface (b). Highlights are obtained with the brush tool (c). The color is accumulated where the user draws (like the pencil tool in image processing software such as © Gimp or © Photoshop), except that each brush is deformed along surface flows when $\alpha > 0$. (c) is then multiplied by the reflectance map (d) to obtain the final result (e).

Figure 4 The image-based material editing example is obtained as follow:

1. (b,c) Start from image (a) to extract depth (b) and normal (c) maps using the image-based material editing technique [Khan et al. 06].
2. (d) Deform a marble image with the first-order operator ($\gamma = 1$) and one single anchor point to mimic texture deformations.
3. (e) Apply the second-order operator on a blurred disk ($\alpha = -1.6, \beta = 1.6$) to create the diffuse layer. change the color of the disk according to the Fresnel value in order to imitate color bleeding between the wall and the cat.
4. (f) Use a smaller disk and a positive stronger deformation ($\alpha = 2.5$) to create highlights.
5. (g) Combine shading layers and multiply them with the textured rendering ($d * (e + f)$) to obtain the final rendering.

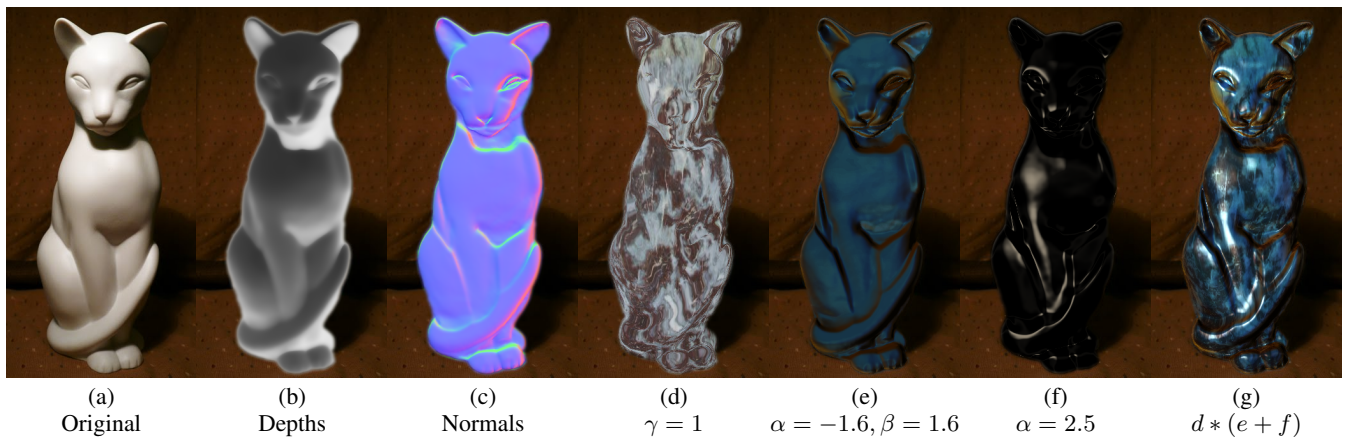


Figure 4: Image-based material editing. A depth map (b) and a normal map (c) are first extracted from an original image (a) using the approach described in [Khan et al. 05]. A single anchor point is used to apply a marble texture in (d), where $\gamma > 0$. The α parameter is then used in (e) to deform a blurred disk. Blue and orange colors were used for front and slanted surfaces, respectively. A single blob is then added and deformed in (f) to create the highlights. The final image (g) is obtained with $d * (e + f)$.

Texture mapping.

Figure 5 A drapping example is shown to illustrate the effect of the first-order operator:

1. (a,b,c) Distort the texture using the image tool and a single anchor point ($\gamma = 2$).
2. (d) Repeat texture generated coordinates to cover the entire table.
3. (e,f,g) Use the brush tool ($\alpha = 0.3$) to produce smooth white (a,b) and yellow (c) reflections.
4. (h) Combine the texture and shading layers ($d * g$).

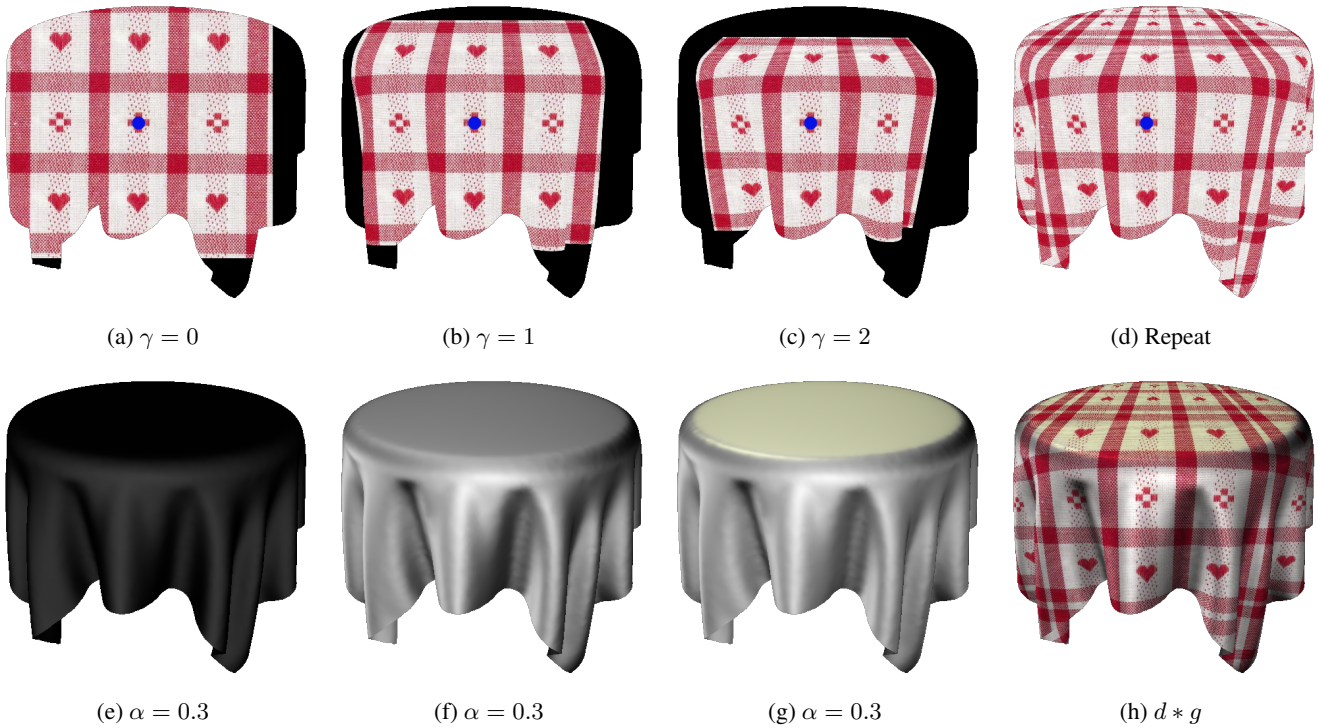


Figure 5: Drapping. Top row: the γ parameter has the effect of mimicking the texture deformation (a,b,c). Texture coordinates are repeated in (d) to cover the entire table. Bottom row: a white (e,f) and yellow (g) blurred disk are applied with a few strokes (using the brush tool) to mimic a diffuse material shaded by a yellow lamp. The texture and the shaded image are multiplied to obtain the final rendering (h).

Material design.

Figure 6 Cliparts are easily created using a few brushes:

1. (top) Create the diffuse layer with a blurred disk ($\alpha = 0.1$) and the highlights using four distorted squares ($\alpha = 2.5$).
2. (middle) Modify the color, blurriness and size of four distorted disks ($\alpha = \{0.4, 0.6, 2.5, 2.5\}$) to produce this result.
3. (bottom) Use negative transformations ($\alpha = \{0, -0.5, -2, -2.5\}, \beta = 1$) to make translucent-like materials.

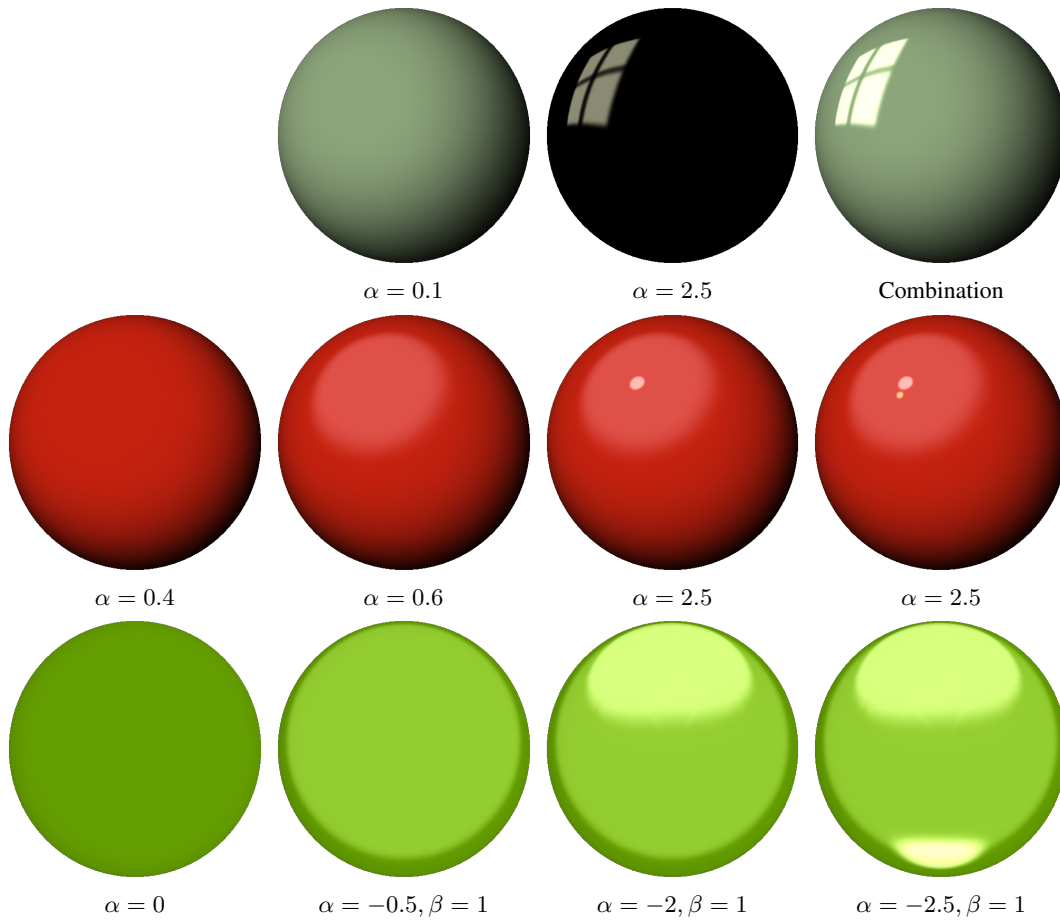


Figure 6: Cliparts. All the cliparts are created using the brush tool and a more or less blurred and colored disk as input (except for the window in which a square was used). $\alpha > 0$ in the two first examples to produce opaque shapes whereas $\alpha < 0$ in the third example to create a stylized translucent material.

Figure 7 this example illustrates how α and β can be manipulated to produce transparency:

1. (b) Set α to -0.5 to mimic refraction patterns using an input image (a) and a single anchor point.
2. (c) Set β to 1.3 to produce a transparent shape. It increases distortions on front faces while keeping deformations on slanted regions.
3. (d) Darken edges to mimic higher absorptions on thick regions.

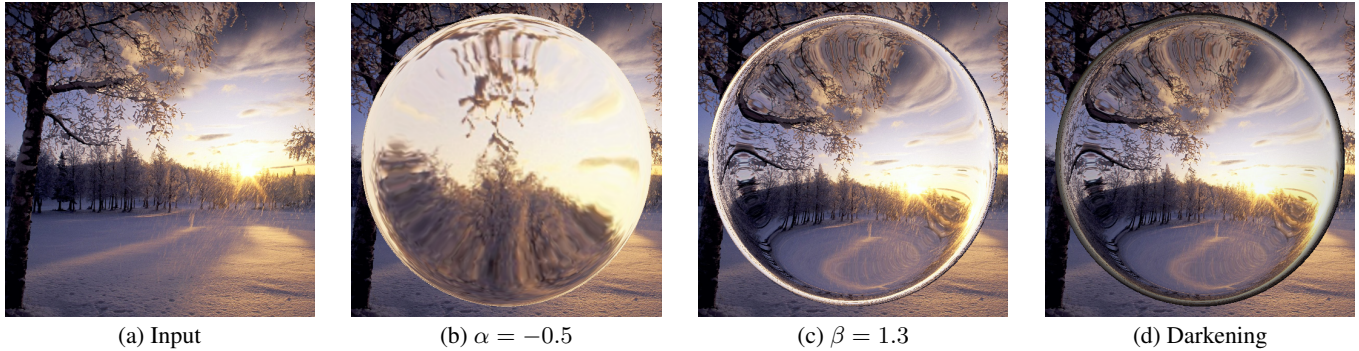


Figure 7: Transparency. The input image (a) is distorted using a single anchor point and $\alpha < 0$ to mimic a refraction effect (b). Increasing β has the effect of limiting distortions on places where the surface is perpendicular to the line of sight (c). Edges are darkened in (d) to produce the final result.

Figure 8 Translucency can be achieved with the same principle, as shown in the top row of this figure:

1. (b,c) Create two refractive-like distortions ($\alpha = -0.75, \beta = 2$) via different blurriness and colors applied to the input image (a).
2. (d) Combine the layers using the Fresnel value to obtain a plausible scattering effect.
3. (e) Add highlights with the brush tool ($\alpha = 2$).
4. (bottom) Modify blurriness and colors of the two refractive layers to obtain many different translucent effects.

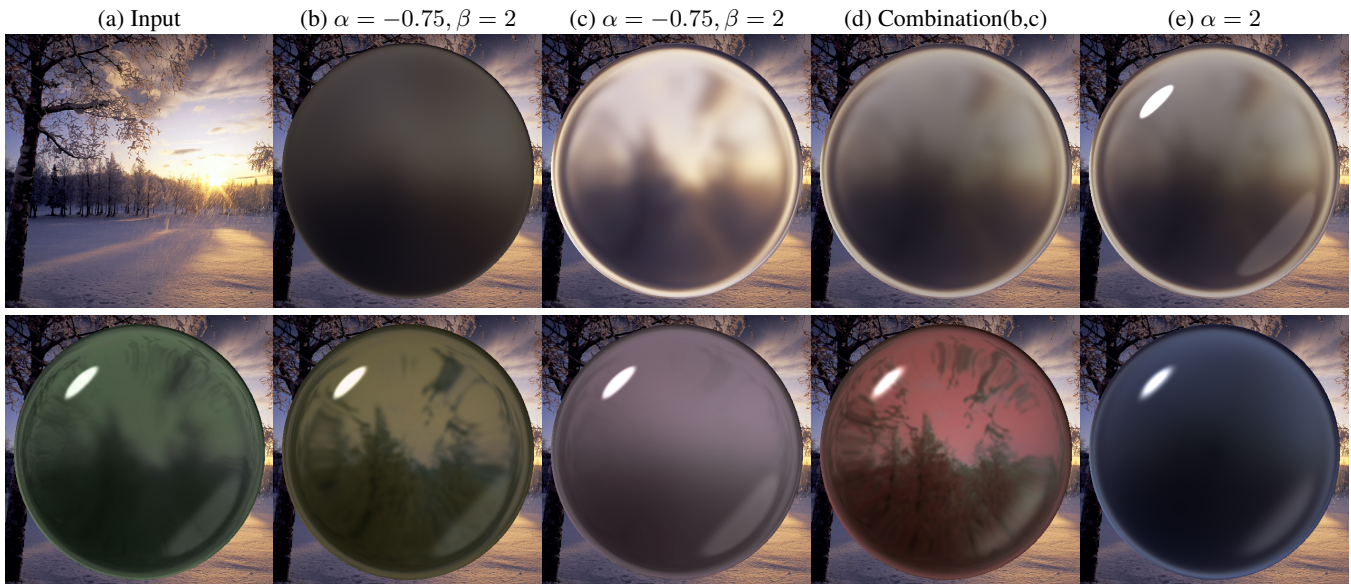


Figure 8: Translucency. The top row illustrates the creation of a translucent material. The input image (a) is blurred and darkened before applying a refractive deformation in (b), where $\alpha < 0$ and $\beta > 0$. The same operation is done in (c) using a brighter and less blurry image. (b) and (c) are combined using the Fresnel coefficient in (d) to mimic absorption / scattering effects. Two highlights are added in (e) using the brush tool and a gaussian disk as input primitive. Modifying color, brightness, and blurriness of the input images yeald to various translucent effects (bottom row).

Figure 9 Fabrics were all obtained via the weighted combination of two distorted brushes:

1. (a) Distort a blurred disk with the brush tool to create a first shading layer (from top to bottom, $\alpha = \{2, 0.5, 2.5\}$).
2. (b) Shift the position of the anchor point and vary the blurriness of the input disk to create a second shading layer so that bright regions appear in slightly different places ($\alpha = \{1, 1, 1.5\}$).
3. (c) Combine the shading layers in order to produce complex shading patterns that mimic multiple BRDF lobes.

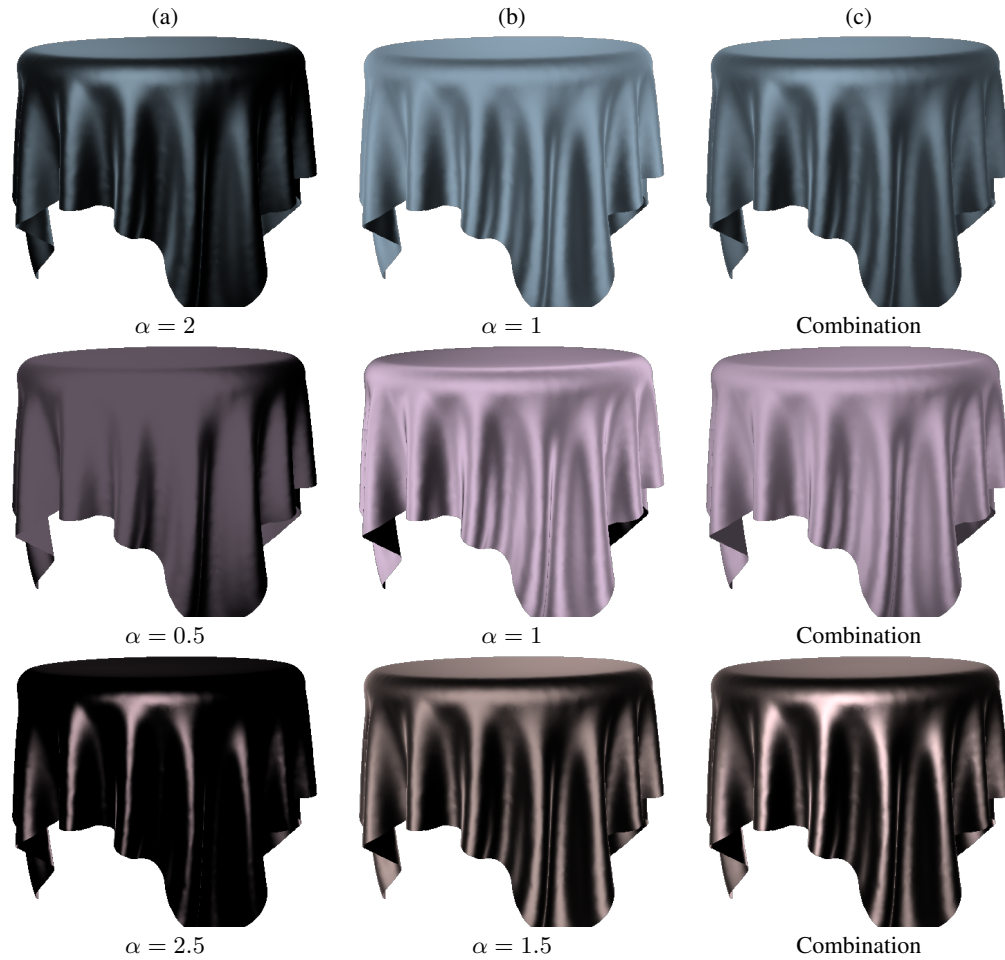


Figure 9: Fabrics. Fabric examples shown in the paper (c) were created via the weighted combination of two brushes (a) and (b). The position, size, sharpness and amount of distortion of the brushes were modulated in (a) and (b) in order to mimic the complex patterns obtained when using multiple BRDF lobes (c).

Photo-realistic imitations.

Figure 10 The mirror material is obtained using the image tool:

1. (b) Use the latitude-longitude environment map which was used to produce the realistic example in the paper (a) and place it on top of the object using a single anchor point.
2. (c,d,e) Increase the deformation until the material looks like a mirror surface ($\alpha = 0.5$).

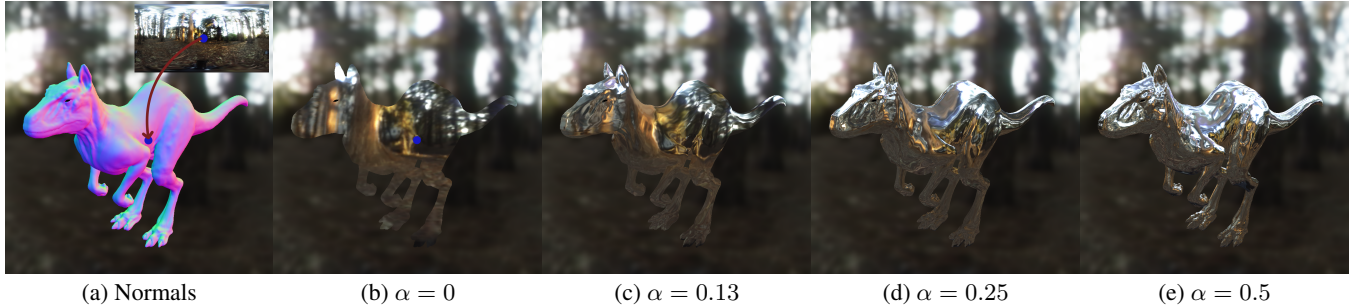


Figure 10: Mirrored material. Starting from a given normal map (a), the original latitude-longitude environment map (Eucalyptus Grove from Debevec's page) is deformed (b,c,d) by increasing α , until the desired result is obtained (e).

Figure 11 This example shows how to mimic a realistic glass material:

1. (a) Place the input image on top of the object using a single anchor point and set β to 2.
2. (b,c) Apply a refractive deformation with the second order operator ($\alpha = -0.7$).
3. (d) Add highlights with the same approach, with a positive deformation ($\alpha = 0.5$).
4. (e) Deform a blurred black disk ($\alpha = -0.6$) with the brush tool to mimic complex absorption effects and improve realism.

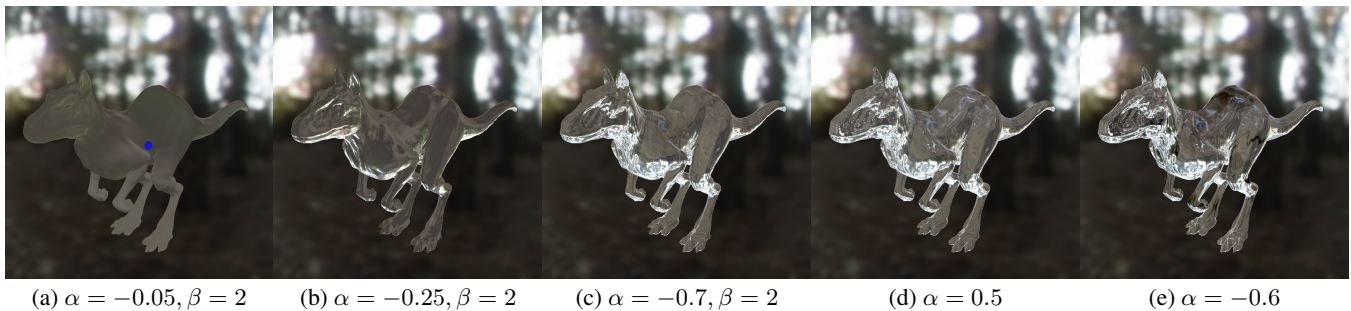


Figure 11: Glass material. The original environment is first distorted using $\alpha < 0$ and $\beta > 0$ to create refraction patterns (a,b,c). In (d), reflections have been added on top of the rendering using the same input map and a value of $\alpha > 0$. Finally, a black deformed gaussian brush is applied to mimic complex absorption/scattering effects obtained with glass materials.

Figure 12 The plastic material is obtained as follow:

1. (a,b,c) Apply the same deformation as for the mirror material ($\alpha = 0.5$) with the environment that has been blurred to produce a diffuse layer.
2. (d) Use the brush tool and a smooth dark disk to mimic shadows ($\gamma = 5$).
3. (e) Create glossy patterns with a few brush strokes and reflective deformations ($\alpha = 1$).

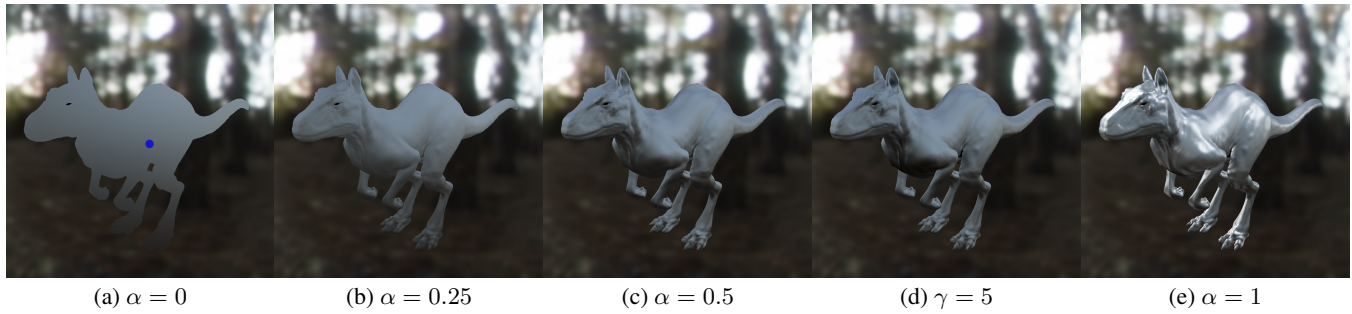


Figure 12: Plastic material. The diffuse layer is created in exactly the same way as for the mirror surface, except that the latitude-longitude input image is blurred to create a matte surface (a,b,c). A simple smooth gaussian brush is then applied in a few locations to produce shadows (d) and highlights (e).

Complex results.

Figure 13 This figure is created using most of the tools presented in the paper:

1. (d) Set γ to 5 to distort the gradient of an image with the first-order flow (b), add it to the original normals (a) and re-normalize to produce bump effects on top of the vase.
2. (e) Starting from the layered normals, use the gradient tool to deform an image and obtain diffuse (vase - $\alpha = 1$) and scattered (statue - $\alpha = -2, \beta = 6$) renderings.
3. (f,g) Distort colored textures $\gamma = 5$ to mimic material variations, such as painting (vase) or marble (statue).
4. (h) Deform a simple squared brush to add highlights on top of the objects ($\alpha = 1$).
5. (i) Use the first-order deformation operator ($\gamma = 5$) and a circular blurred brush to produce shadows.

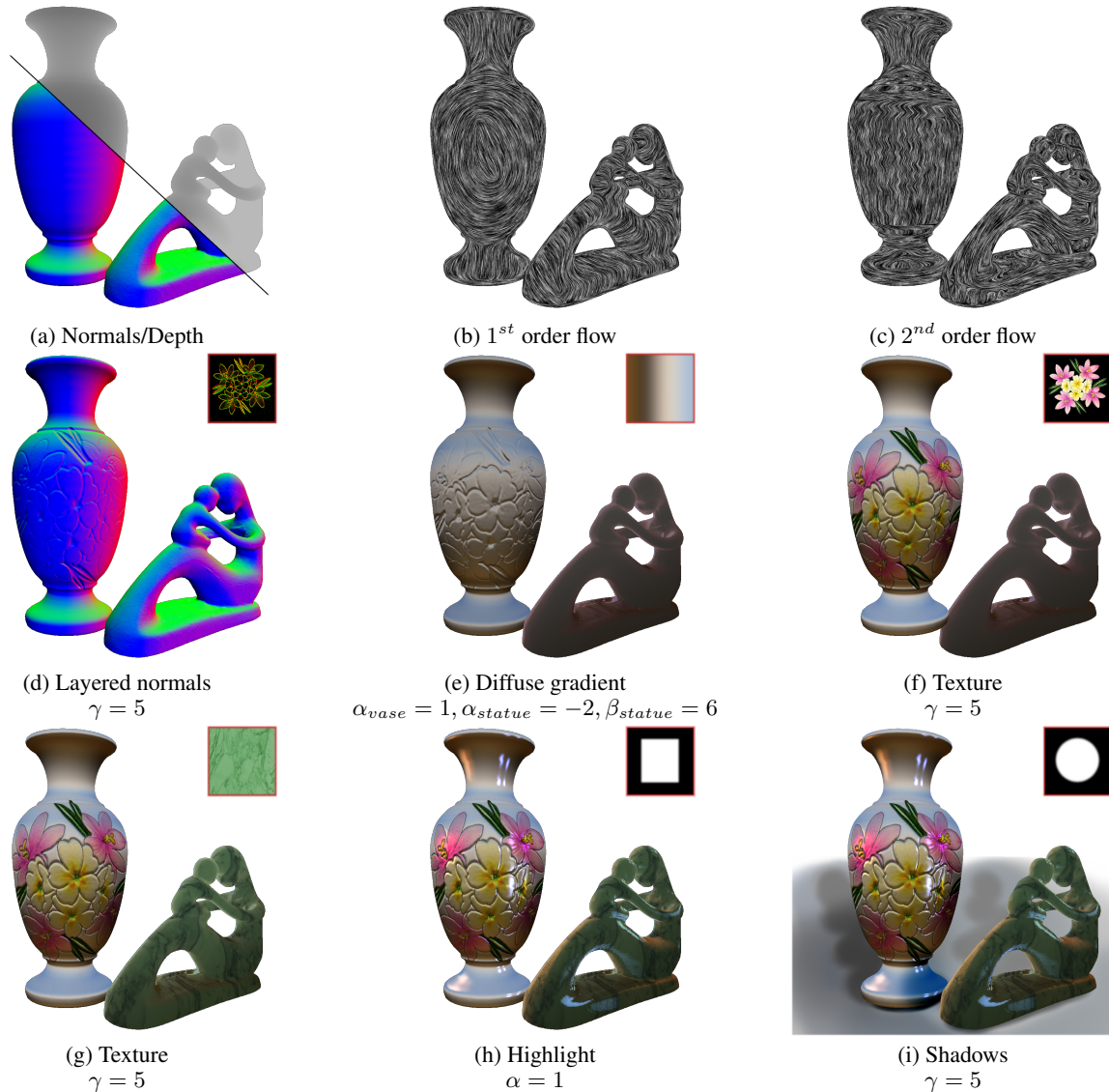


Figure 13: Textures and shading. (a) Normal and depth maps. (b) Shading flow. (c) Texture flow. (d) Vase normals are modified using the gradient of an image to produce a bump mapping effect. (e) Distorted gradient that mimic either a diffuse component (vase) or a scattering effect (statue). (f) Colored texture multiplied with the diffuse component on top of the vase. (g) Marble applied in the same way to the statue. (h) Highlights added using a simple squared brush. (i) Texture deformations are used to paint shadows.

Figure 14 In Figure 14, we show how to easily mimic translucent materials:

1. (b) Starting from input normals (a), produce specular reflections via the deformation of a single image and a single anchor point ($\alpha = 1.4$).
2. (c) Perturb normals with a noise texture ($\alpha = -0.25$) in order to imitate multiple bounces in the refraction process.
3. (d) Use the normal map created in (c) as a starting point to distort a blurred image of the same scene for mimicking scattering deformations ($\alpha = -0.25$).
4. (e,f) Combine the specular and refraction components according to the Fresnel coefficient. Confirming Motoyoshi's suggestion, the result looks more realistic when normals are disturbed for mimicking the scattering effect (f).

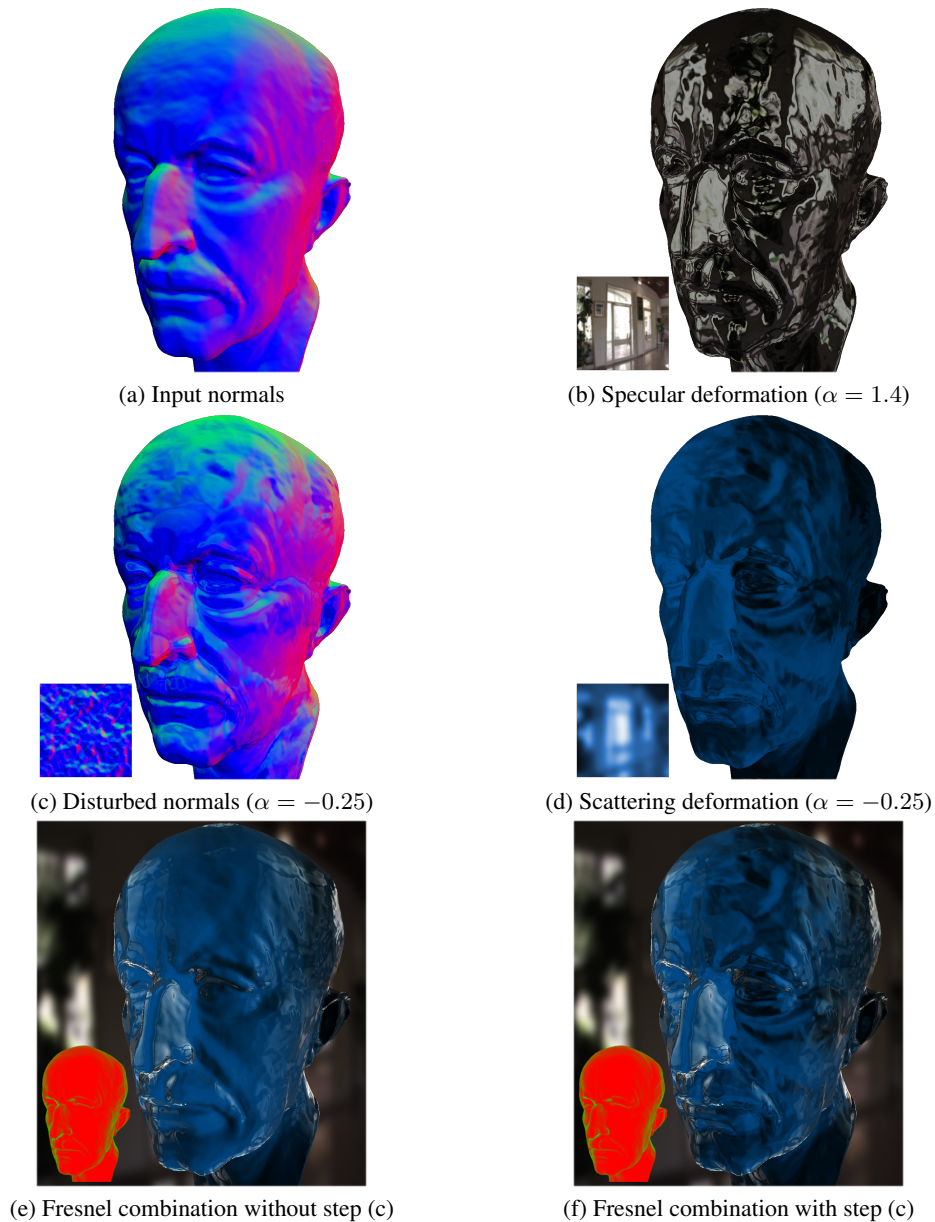


Figure 14: Translucency. (a) Input normal map. (b) A specular deformation is applied starting from a single image. (c) Normals are disturbed using a noise input texture. (d) The scattering effect is obtained using the disturbed normal map and a blurred input image. (e) Combination of specular and scattering components using the Fresnel coefficient (original normals were used for the scattering effect here). Realism is better when using disturbed normals (f) as it mimics front and back faces variations.