3D Unsharp Masking for Scene Coherent Enhancement
Supplemental Material: Rendering

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1 Enhancement of Luminance Texture

Under our enhancement, the luminance changes created by a texture are also enhanced. As we found with the book example, this simply means the enhancement is less robust to changes in radius and enhancement strength - users may choose a weaker effect to avoid enhancing the textures. Or, should the user have special reason not to enhance texture at all, he or she may choose to render in two passes (one with reflected lighting, one with texture), enhancing only the textureless pass and then recombine (note that this restricts the scene to diffuse textures). However, as shown in the book example (Figure 5 and by the user study on that image, pleasing enhancements can be achieved by adjusting σ and λ. Another example of a zebra whose stripes are a luminance texture, explicitly shows how we seamlessly enhance textures (Figure 1).

2 Animated Examples

We give two simple examples of 3D unsharp masking in the supplemental video - the first with rigid body movement only, and the second with a smooth deformation. In these types of cases, we have found the direct application of our approach leads to temporally coherent enhancements. However, we did not investigate the problem of smoothing lighting over the mesh when topology changes or when there are intersections. We consider this work to be an area of future work, but are encouraged by the high quality enhancements of these simple scenes, as shown in Figure 2.

3 Mesh Dependence

The mesh structure and quality affects the results of our enhancements, just as it affects many Computer Graphics approaches that work on meshes. A very low quality mesh will give an irregular smooth signal and a less smooth Cornsweet profile, and as with most mesh processing algorithms, a mesh works best when it has uniform vertex density, uniform areas and angles, no isolated triangles or gaps and constant topology.

The smoothness parameter, σ, is the number of smoothing iterations applied to the lighting over the mesh. Since sigma depends on the mesh tessellation, and that the mesh quality affects the smoothing over the mesh, so the smooth signal may be more or less evenly/consistently smoothed depending on mesh structure. If the mesh is of lower initial quality and no automatic mesh repair solution is available one can always choose a stronger smoothing (high σ) so that visible meshing will be blurred out. We show an example of this in Figure 3.

4 Performance Details

The performance of our method is detailled in Table 1.

System The system used is an Intel Core 2 Duo 6300 with 2 GB RAM and an NVIDIA GeForce 8800 GTX.

Supersampling All tests were done at the resolution of the video, which is 640×480. For some sufficiently fast scenes, we supersampled from 1280×960 to 640×480 using a box filter.

Lighting We use different shaders for different scenes. Some scenes use simple OpenGL point lights with orthogrpahic or cube shadow maps. For natural illumination, we convert the light probe into a number of point lights and a number of shadow maps [Havran et al. 2005]. For the 'Columns' scene, we use pre-computed ambient occlusion (AO) and store it for with every vertex, which is common practice in games.

5 Rendering Details

Feet The 'Feet' (See Fig. 4) uses the well-known 'Uffizi' light probe. We use 32×32 lights in the study and 16×16 lights in the video. The depth maps share a single 8192×8192 texture. Only the ground-plane was tesselated to allow for Laplacian smoothing.

Dice The 'Dice' (See Fig. 5) uses a single point light with a 2048×2048 cube shadow map. It uses a texture atlas, which can sometimes show artifacst at texture chart borders with minification which is a well known problem but not relate to our technique. Only the ground-plane was tesselated to allow for Laplacian smoothing.

Keys The 'Keys' (See Fig. 6) uses a single point light with a 2048×2048 cube shadow map. We use the Blinn-Phong shading modell with a roughness of 0.8, a dark grey for the diffuse and a strong white as the specular color. Only the ground-plane was tesselated to allow for Laplacian smoothing.

Columns The 'Keys' (See Fig. 7) uses a directional light with a 4096×4096 shadow map. The scene required additional tesselation to support Laplacian smoothing.

Chamfer The 'Chamfer' (See Fig. 8) uses the well-known 'Kitchen' light probe. Some objects were authored with rounded and some with discontinuous edges. We use 32×32 lights in the study and 16×16 lights in the video. The depth maps share a single 8192×8192 texture. Only the ground-plane was tesselated to allow for Laplacian smoothing.

Golfball The 'Golfball' (See Fig. 9) uses the well-known 'Beach' light probe. We use 32×32 lights in the study and 16×16 lights in the video. The depth maps share a single 8192×8192 texture. Only the ground-plane was tesselated to allow for Laplacian smoothign.

Cross The 'Cross' (See Fig. 10) uses the well-known 'Beach' light probe. We use 32×32 lights in the study and 16×16 lights in the video. The depth maps share a single 8192×8192 texture. Only the ground-plane was tesselated to allow Laplacian smoothign.

Lucy The 'Lucy' (See Fig. 11) uses the well-known 'Beach' light probe. We use 32×32 lights in the study and 16×16 lights in the

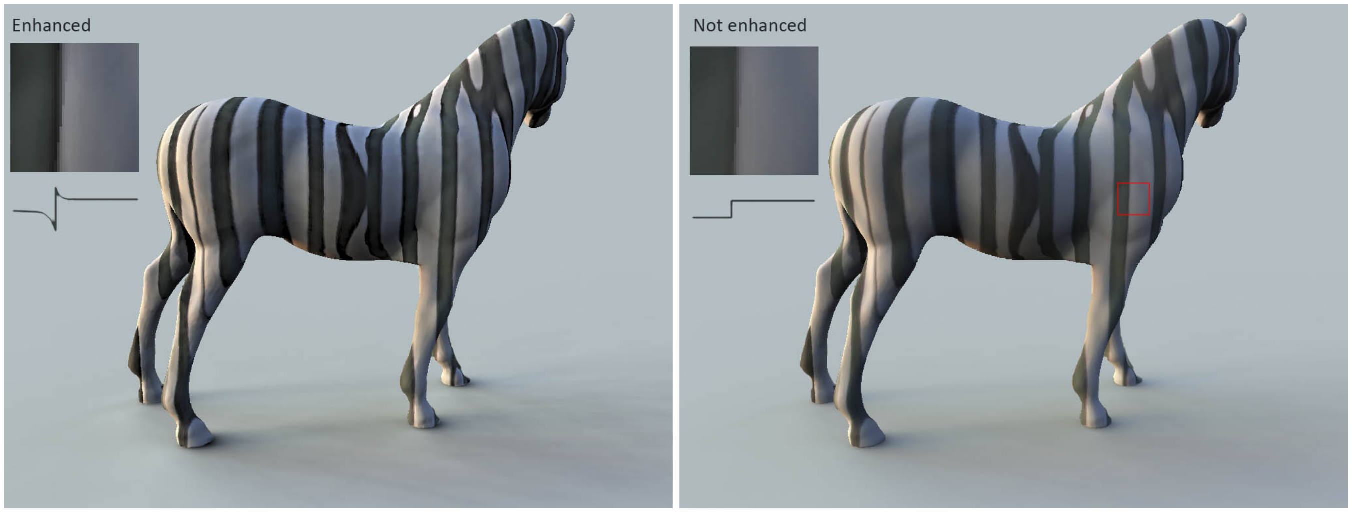


Figure 1: *The zebra's stripes are given enhanced contrast using the 3D unsharp masking approach.*

video. The depth maps share a single 8192×8192 texture. Only the ground-plane was tesselated to allow Laplacian smoothign.

6 Comparison to Previous Approaches

We find that our work is most related to three enhancement techniques: normals sharpening [Cignoni et al. 2005], exaggerated shading [Rusinkiewicz et al. 2006] and depth unsharp masking [Luft et al. 2006]. To compare to the results these techniques achieve, we have created our own 'Cross' mesh (Figure 12), and attained access to the 'Golfball' mesh (Figure 13) and the 'Foot' mesh (Figure 14). We have chosen σ and λ values that we prefer, however enhancement preferences are subjective, so if the effect appears too weak or too strong, it is easily adjusted, as shown by our user study described in the paper.

References

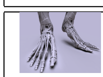
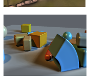
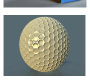
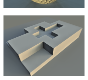
CIGNONI, P., SCOPIGNO, R., AND TARINI, M. 2005. A simple normal enhancement technique for interactive non-photorealistic renderings. *Computer & Graphics 29*, 1.

HAVRAN, V., SMYK, M., KRAWCZYK, G., MYSZKOWSKI, K., AND SEIDEL, H.-P. 2005. Importance Sampling for Video Environment Maps. In *Eurographics Symposium on Rendering 2005*, ACM SIGGRAPH, Konstanz, Germany, K. Bala and P. Dutré, Eds., 31–42,311.

LUFT, T., COLDITZ, C., AND DEUSSEN, O. 2006. Image enhancement by unsharp masking the depth buffer. *ACM Trans. Graph. 25*, 3, 1206–1213.

RUSINKIEWICZ, S., BURNS, M., AND DECARLO, D. 2006. Exaggerated shading for depicting shape and detail. *ACM Trans. Graph. SIGGRAPH 25*, 3, 1199–1205.

Table 1: *Frame rates for different scenes.*

	Scene	Lighting	FPS			Vertices	Iterations	Time		Supersampling	
			Total	Without	Overhead			Lighting	Smoothing	Surface	Framebuffer
	Feet	Natural	10.2	15.2	33 %	57 k	5	26.5	3.7	no	none
	Dice	Point	15.6	63.0	75 %	74 k	1	1.7	4.9	yes	2×2
	Keys	Point	15.2	63.0	76 %	152 k	20	5.1	34.0	no	2×2
	Columns	Point, AO	28.3	63.2	55 %	119 k	2	7.5	2.5	no	2×2
	Chamfer	Natural	8.3	10.7	22 %	39 k	2	20.0	10.1	no	none
	Golfball	Natural	17.9	31.3	43 %	127 k	8	14.3	10.3	no	none
	Cross	Natural	10.9	12.4	16 %	8 k	10	7.2	4.7	no	none
	Lucy	Natural	9.5	37.5	75 %	262 k	40	16.3	62.2	no	none

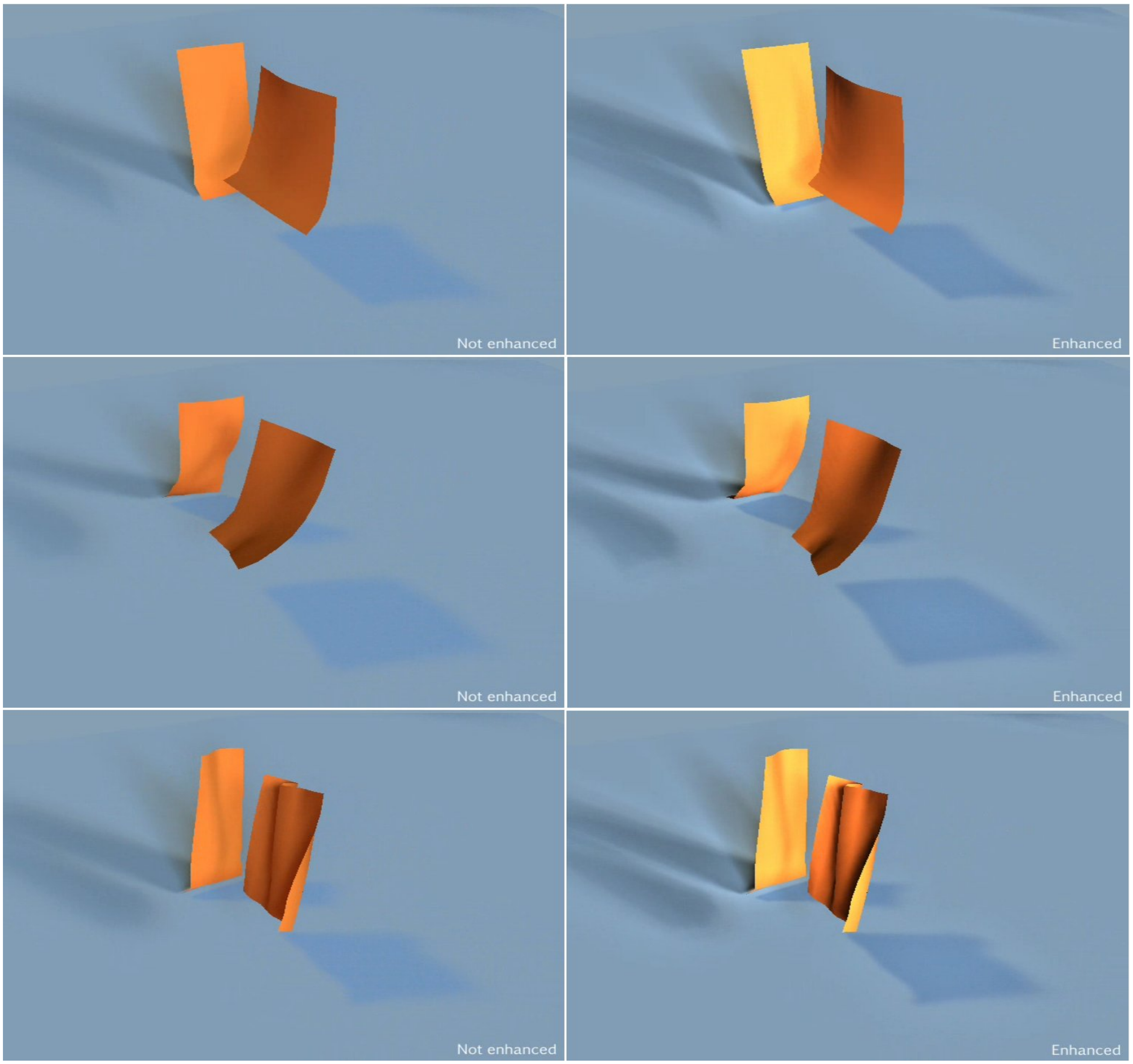


Figure 2: *Three frames from a simple example of an enhanced animation of a deforming model. In simple cases, without topological changes, temporal coherence is preserved and the 3D unsharp masking can be applied.*

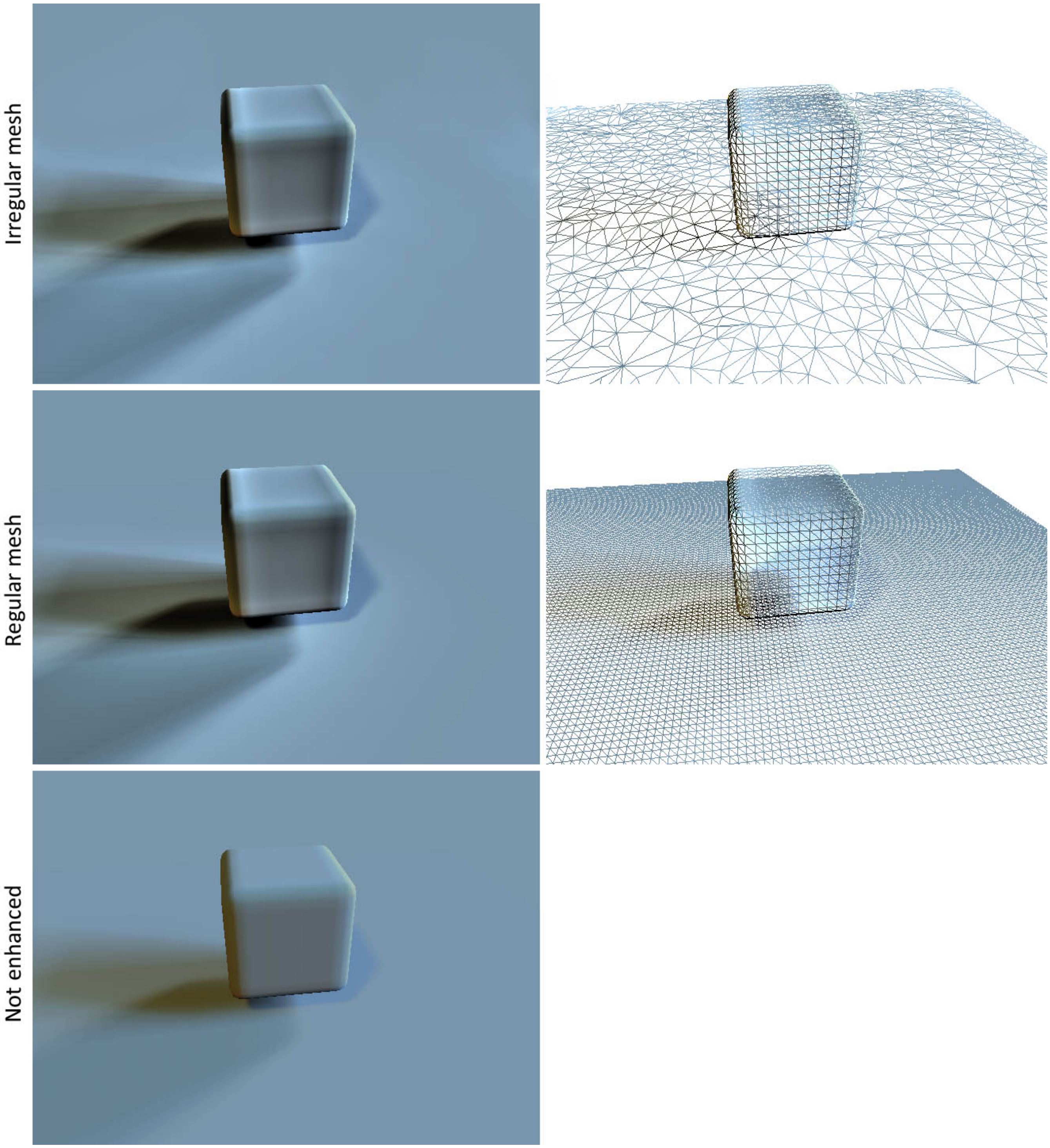


Figure 3: *When the number of smoothing iterations (σ) is sufficiently high, irregular tessellation does not change the quality of the enhancement. This is because the stronger smoothing blurs the visible meshing artifacts.*

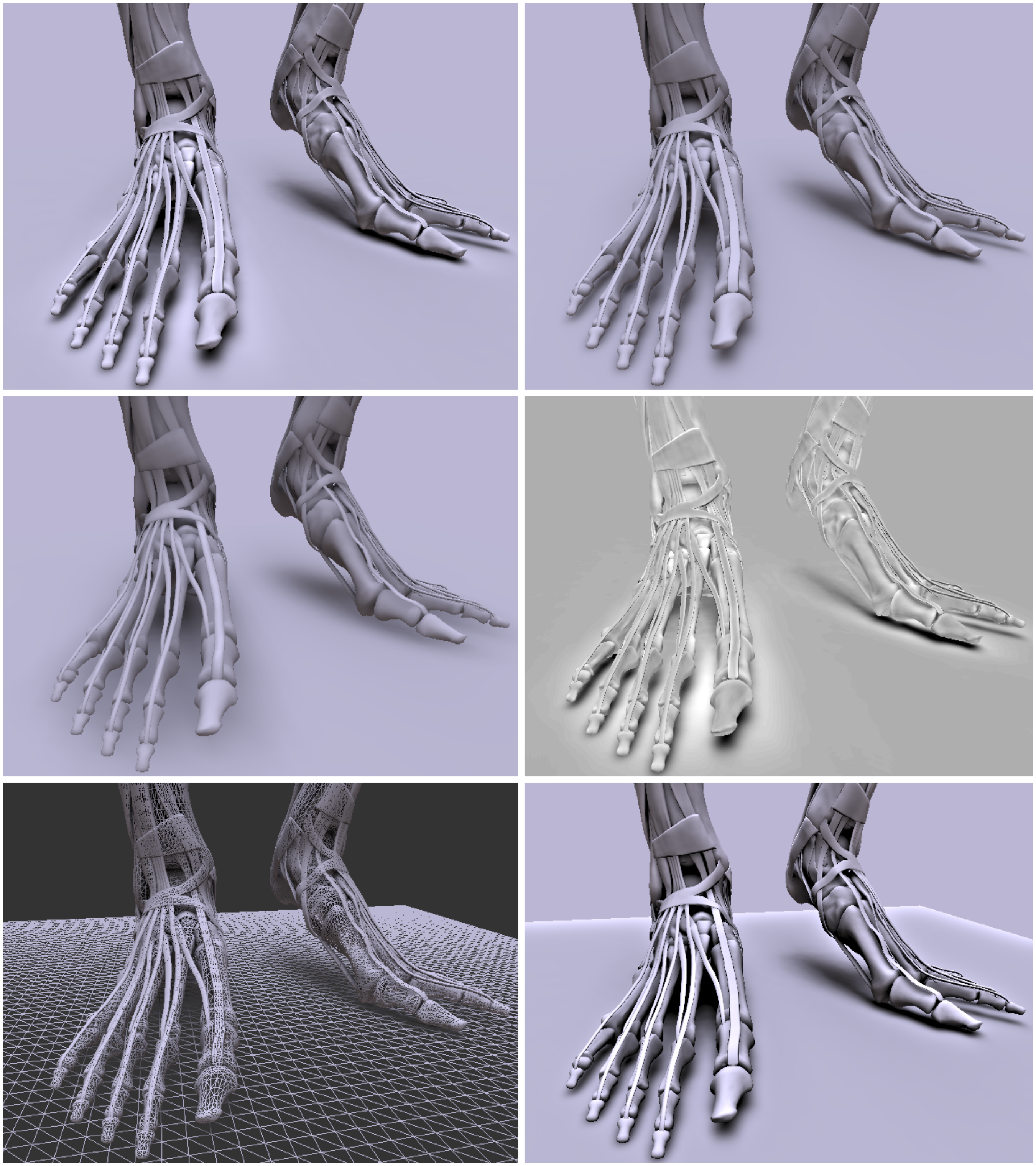


Figure 4: *Feet (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

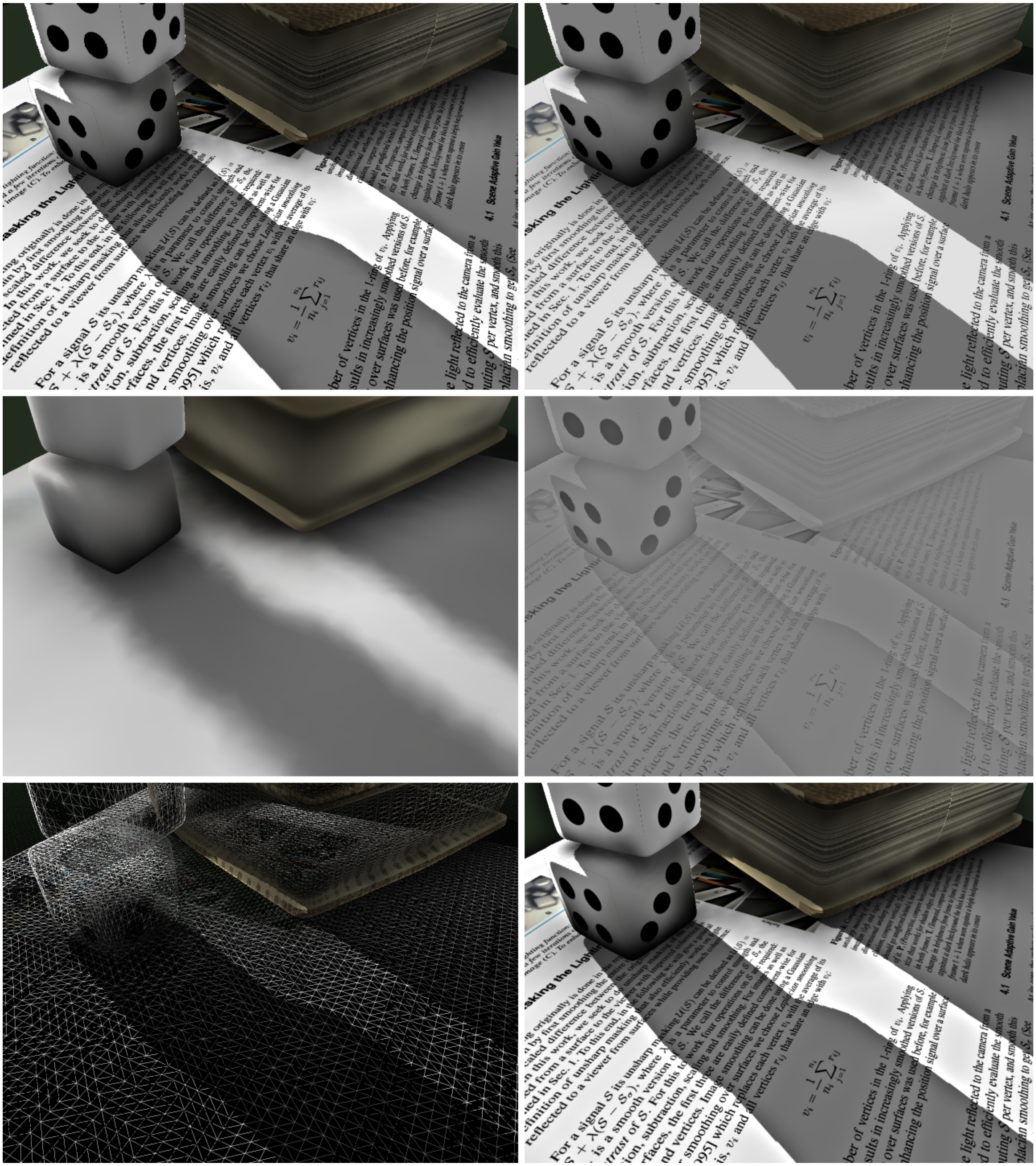


Figure 5: *Dice (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

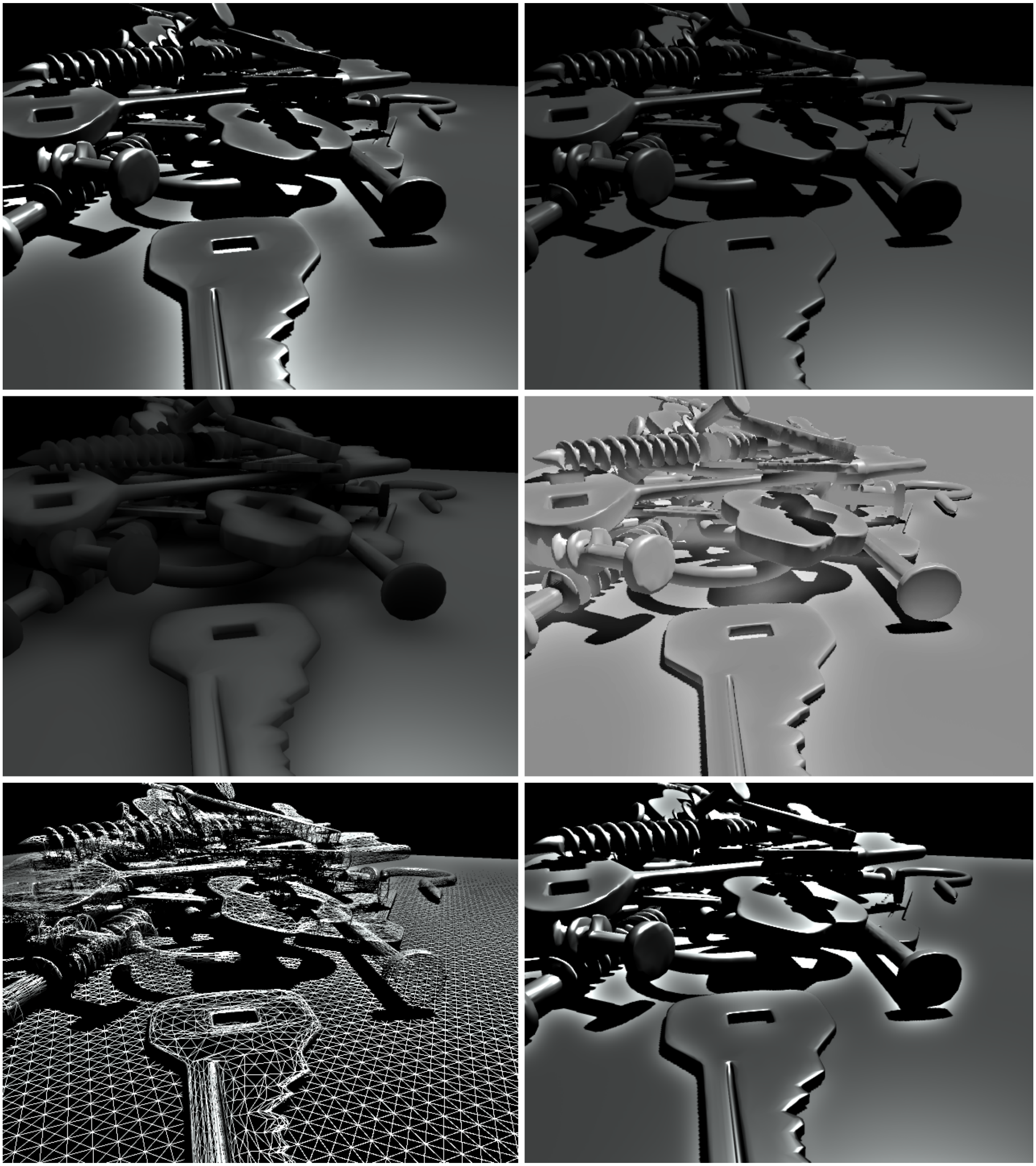


Figure 6: *Keys (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

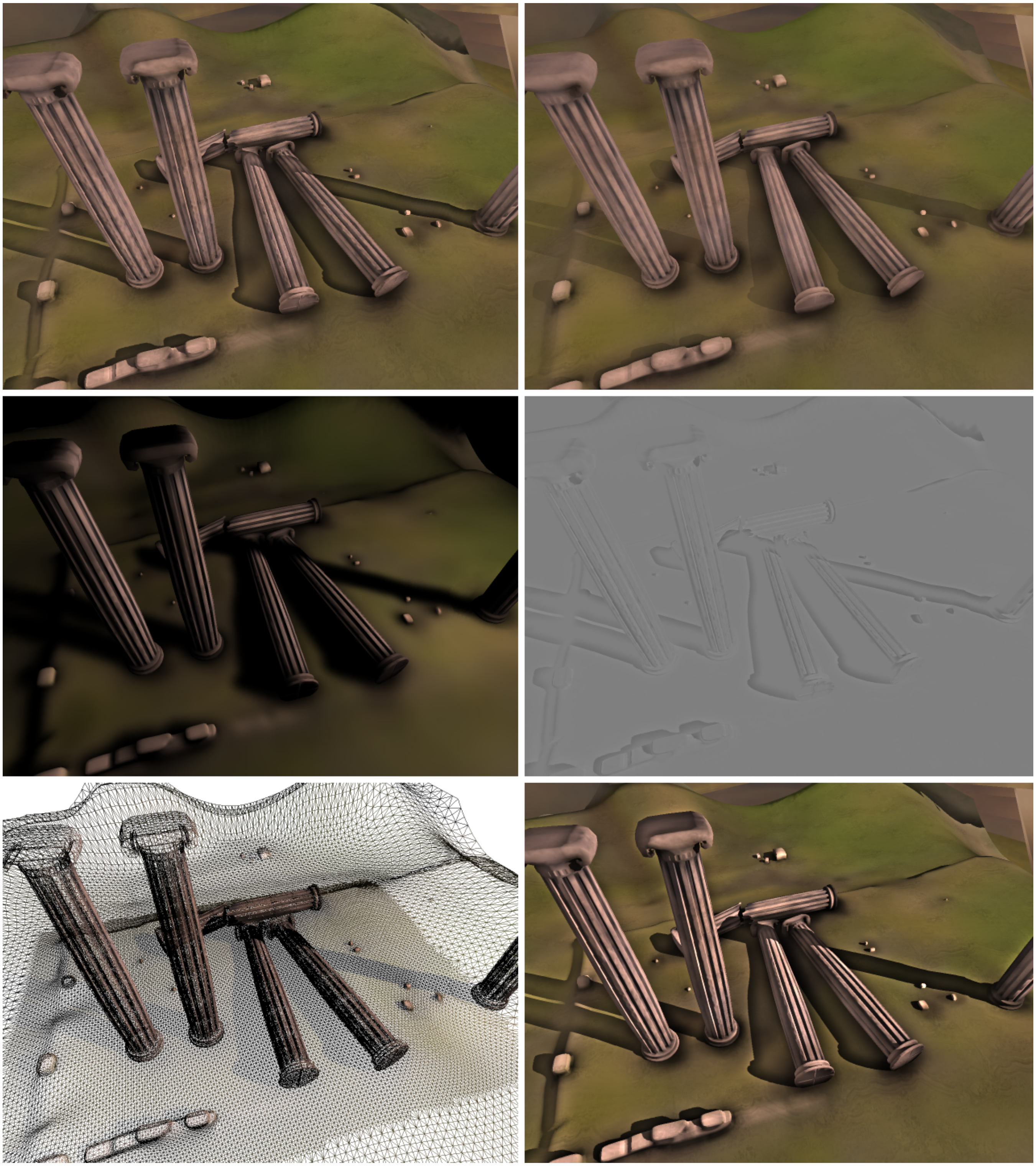


Figure 7: *Columns (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

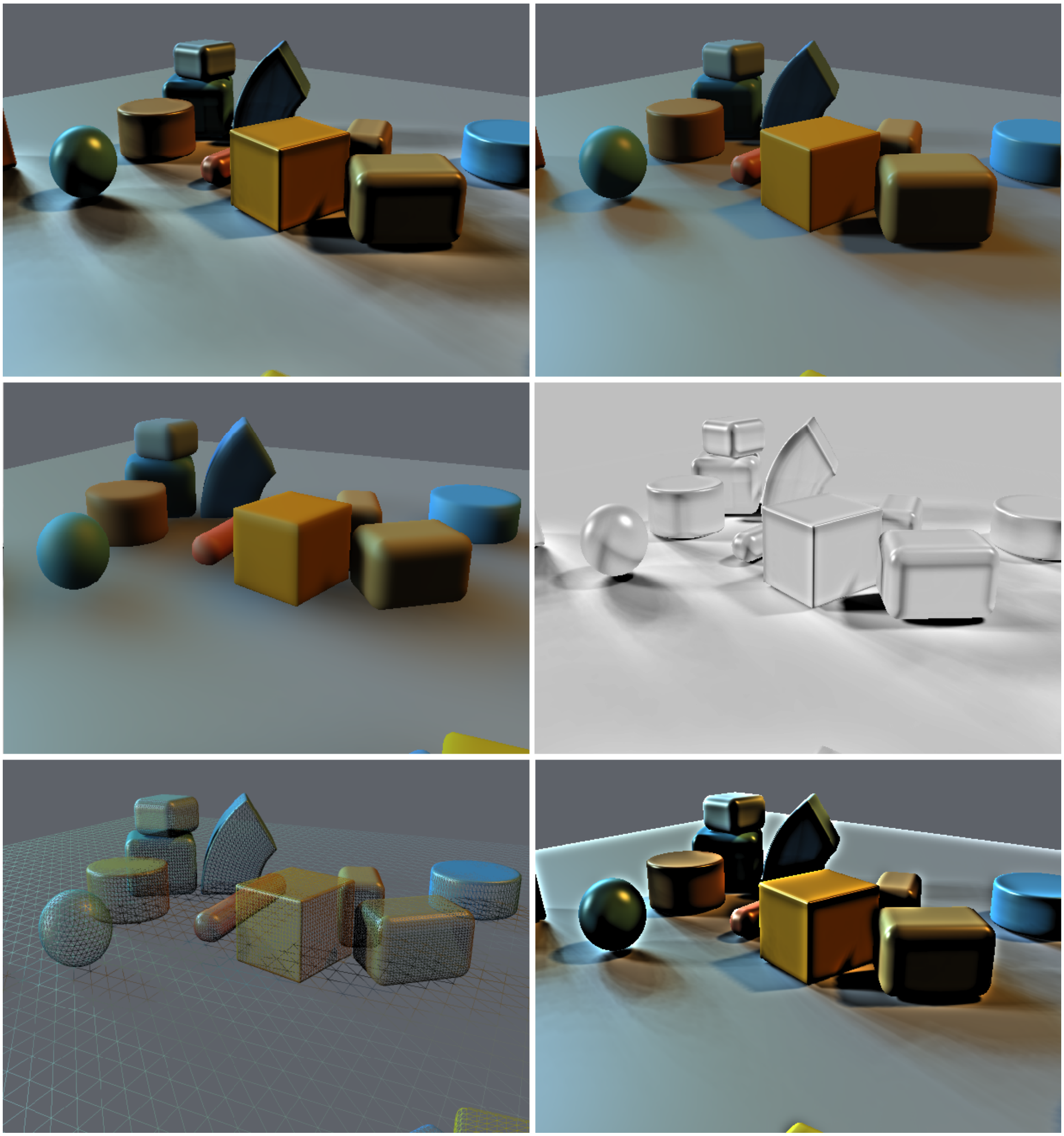


Figure 8: *Chamfer (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

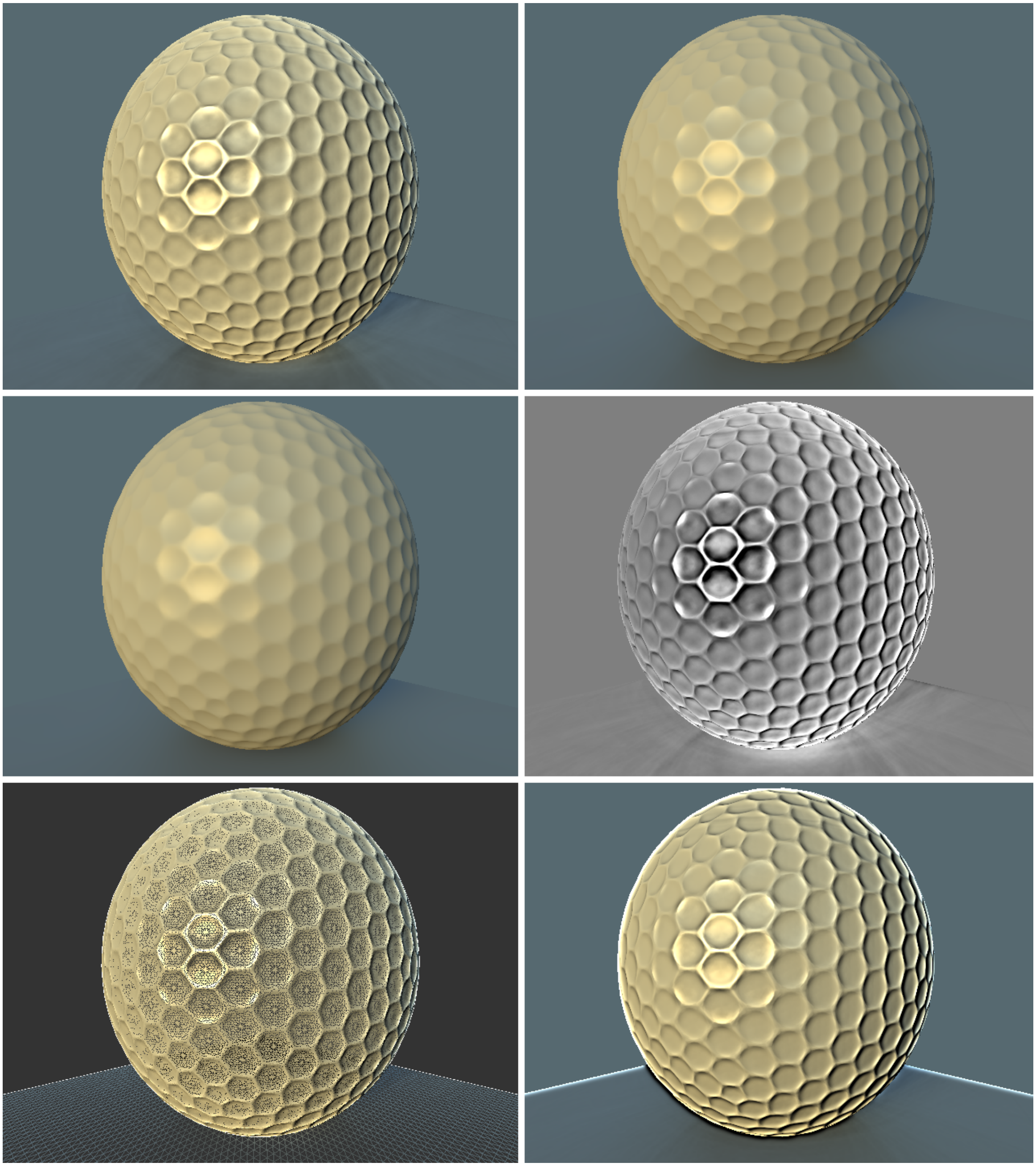


Figure 9: *Golfball (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

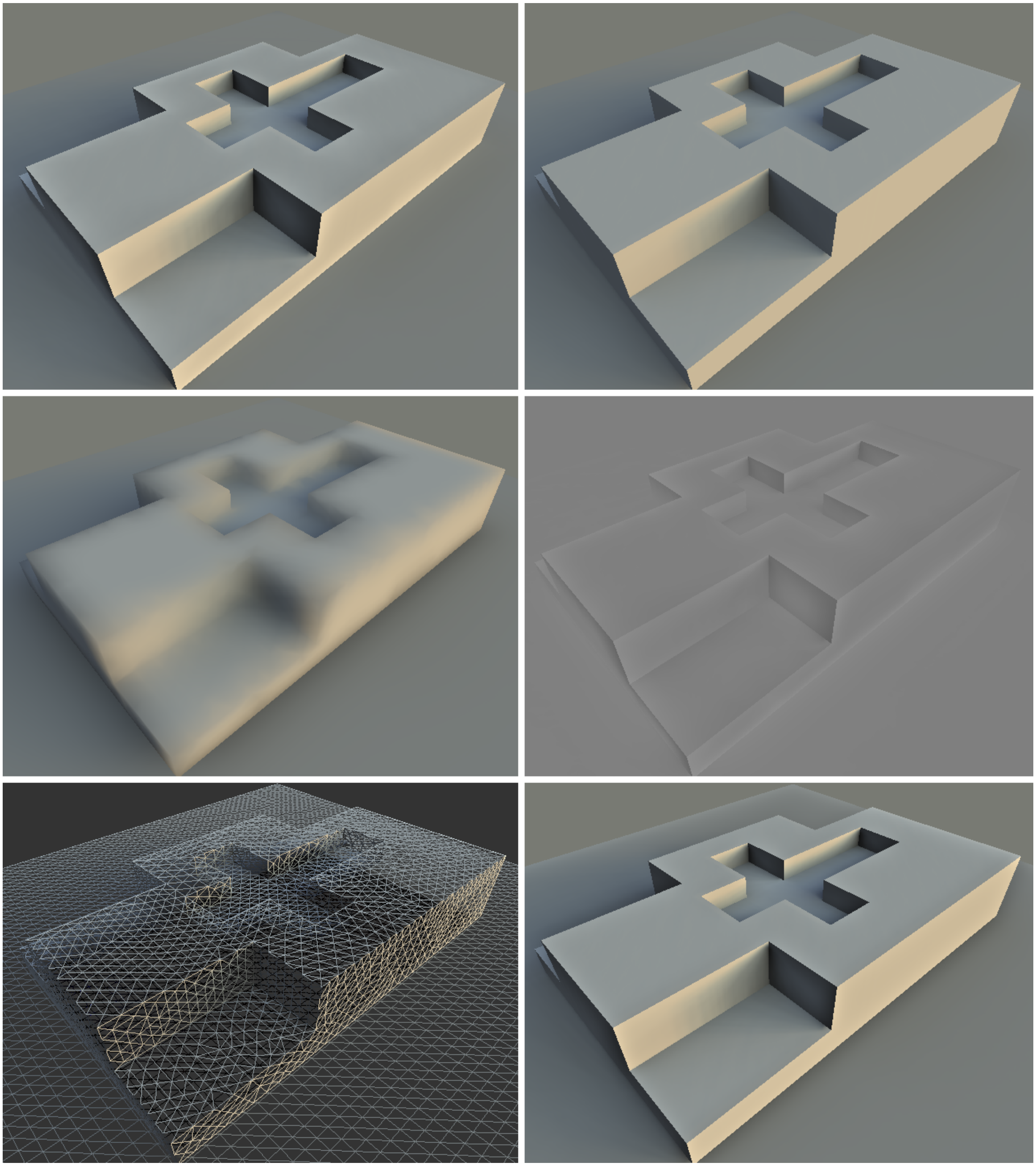


Figure 10: *Cross (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

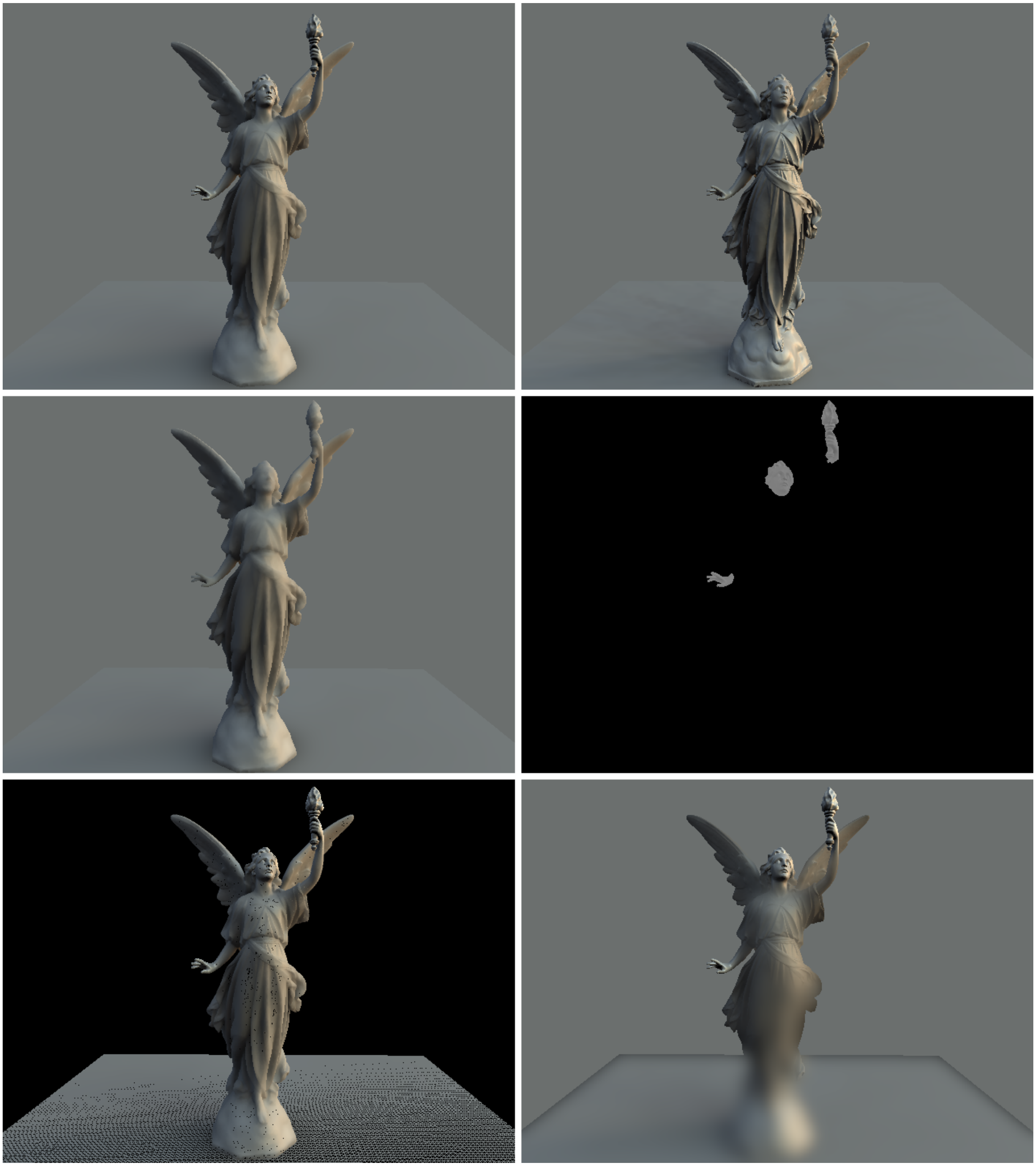
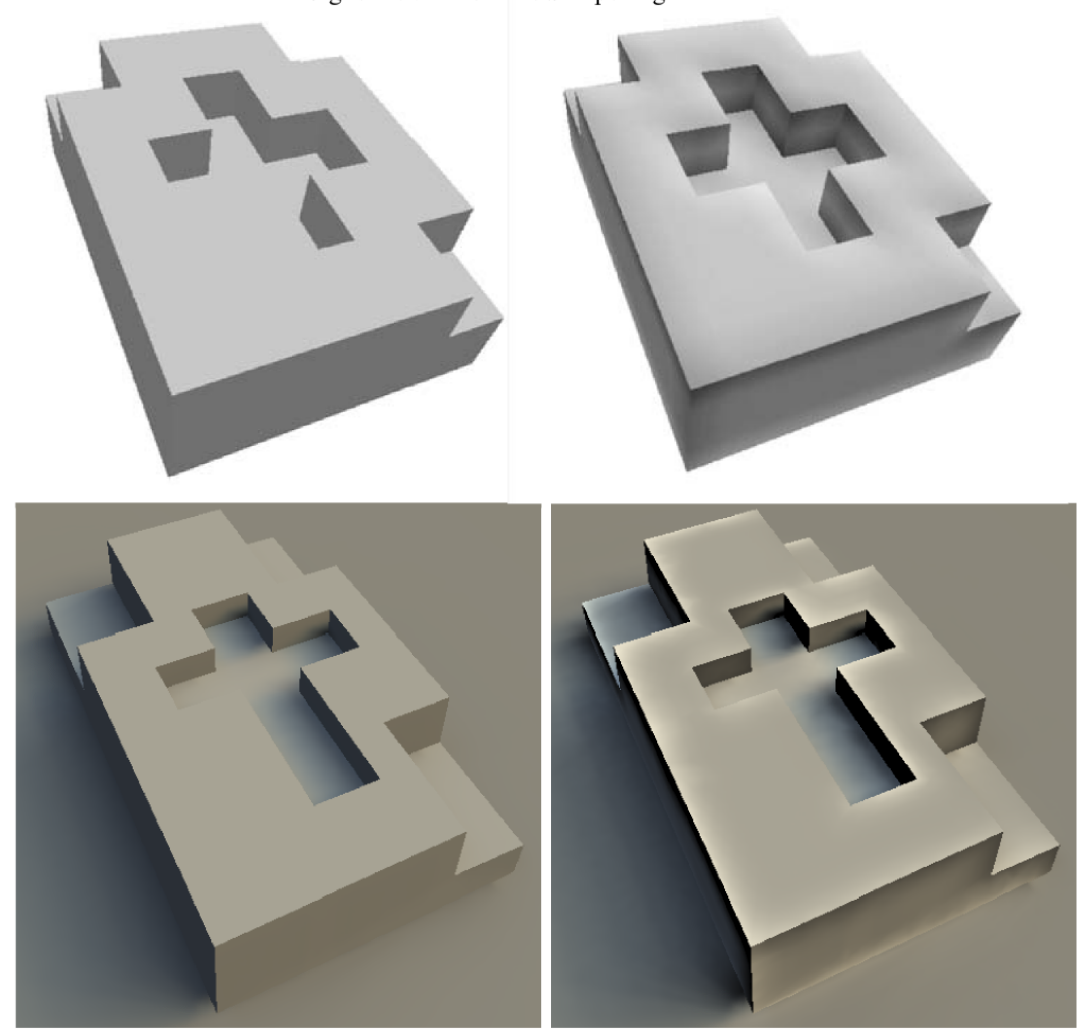


Figure 11: *Lucy (Enhanced, Original, Smooth, Contrast, Wireframe, 2D)*

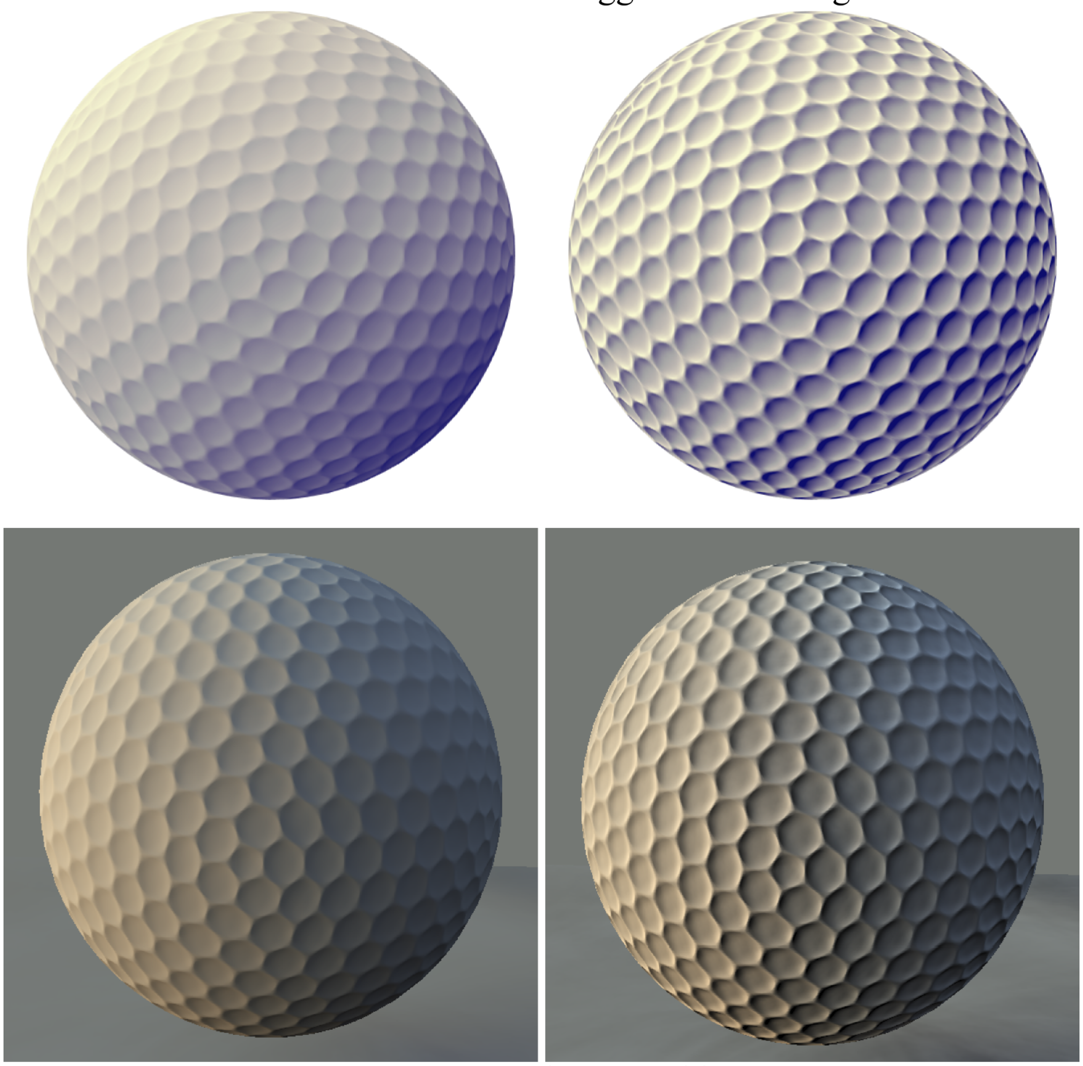
Cignoni et. al Normals Sharpening



Our 3D Unsharp Masking

Figure 12: *Original (left), Enhanced (right).*

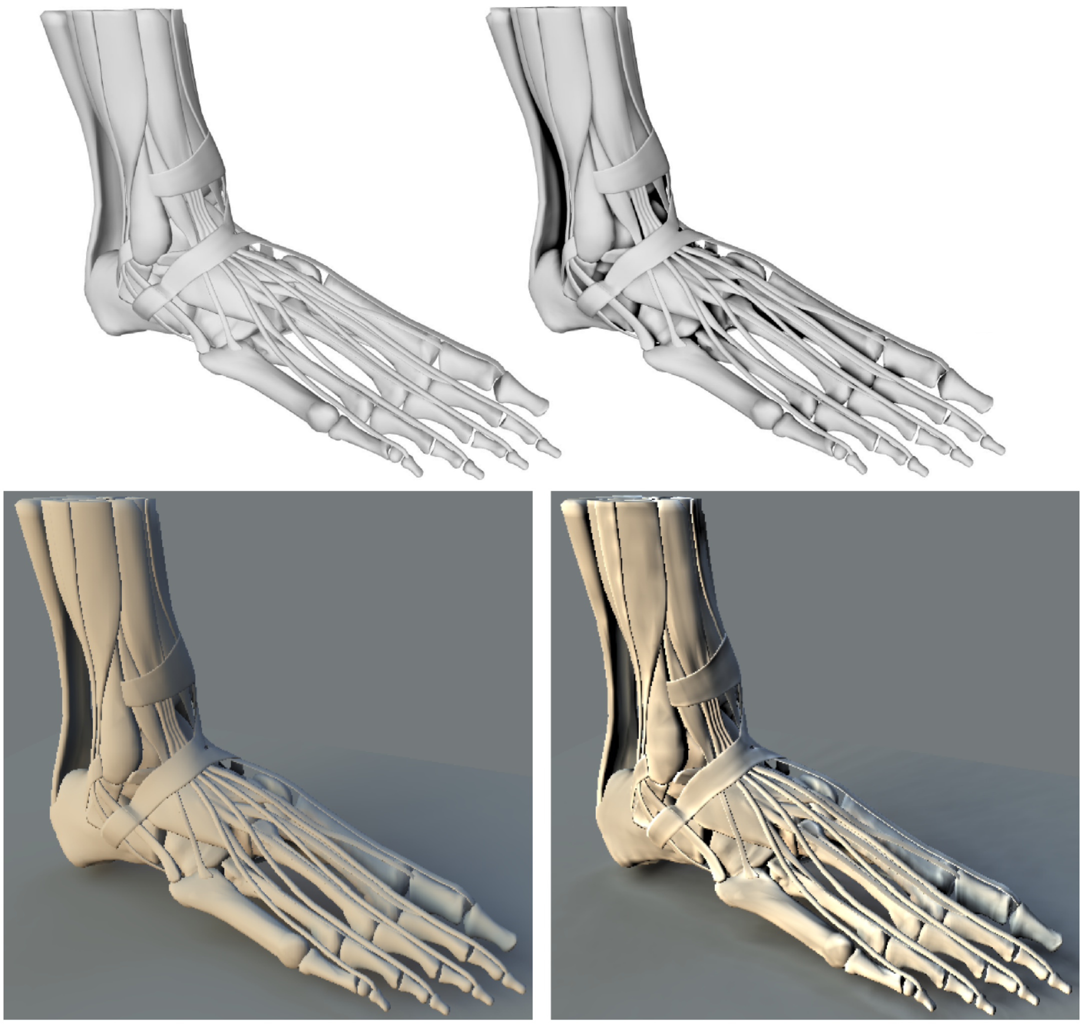
Rusinkiewicz et al. Exaggerated Shading



Our 3D Unsharp Masking

Figure 13: *Original (left), Enhanced (right).*

Luft et al. Unsharp Masking of the Depth Buffer



Our 3D Unsharp Masking

Figure 14: *Original (left), Enhanced (right).*