Shading-Interval Constraints for Normal Map Editing

Shiming Zou, Hongxin Zhang, Xavier Granier

Shading-Interval Constraints for Normal Map Editing

Shiming Zou * Hongxin Zhang† Xavier Granier‡
State Key Lab of CAD&CG, Zhejiang University, China INRIA Bordeaux University, France

Abstract

Normal mapping is a compact representation to create visually rich shapes and shading effects. In this paper, we introduce a new paint-based approach to edit a normal map according to the intended shading, from realistic to non-realistic ones. For this purpose, we have formulated a normal-from-shading operation as a quadratic problem that makes use of intervals on shading. This approach ensures that the resulting normal map visually corresponds to the user-designed shading.

CR Categories: I.3.6 [Methodology and Techniques]: Interaction techniques—Editing; I.3.5 [Computational Geometry and Object Modeling]: Color, shading, shadowing, and texture—Real-time

Keywords: Normal map, Normal from Shading, Paint-based interface

1 Introduction

In computer graphics, the usage of a simple normal map with a coarse 3D geometry has been proven to be visually efficient to model complex 3D worlds. However, editing a normal-map is non-trivial since it is an intangible information only visualized by the its interaction with some light sources. In general, it requires a good understanding of lighting phenomena and geometry to achieve the intended visual results.

In our approach, the user directly paints his expected shading (realistic or non-photorealistic) and the system infers the corresponding normal map. For this achievement, we extend the classical equality constraint of Shape from Shading to an interval-based constraint (Figure 1). These weakened constraints are well suited to the classical quantization on 255 levels for display, to toon-shading [Decaudin 1996], and to take into account perceptual metrics using visual difference and predictors [Daly 1993]. Therefore, our system will ensure that the visual difference between the drawn image and the resulting solution will not be noticeable.

2 Editing with Shading-Interval Constraints

From a user-edited shading, we want to infer the new normals while preserving as much as possible the original apparent shape. For geometry editing, recent work [Botsch and Sorkine 2008] have shown that minimizing the change of Laplacian leads to the preservation of original shape details. We thus introduce a similar operator that works on per-pixel normals in image space:

$$D(\boldsymbol{n}_j) = \boldsymbol{n}_j - \frac{1}{|V_j|} \sum_{k \in V_j} \boldsymbol{n}_k \,, \qquad (1)$$

where V_j is the set of neighboring normals of $\boldsymbol{n}_j$ and $|V_j|$ indicates the size of set V_j ($|V_j| = 4$ in our implementation).

*zhedafantasy@gmail.com
†zhx@cad.zju.edu.cn
‡xavier.granier@inria.fr

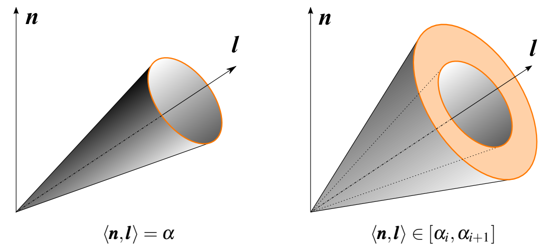

Figure 1: Classical Shape from Shading (left): the angle between the estimated normal and the light direction is fixed. Shape from Interval Shading (right): this angle belongs to an interval.

The new normal map has to both minimize the changes on this operator, but also fulfill the shading interval constraints introduced by user-drawn shading. This results into the quadratic problem:

$$\min \sum_j \left\| D\boldsymbol{n}'_j - D\boldsymbol{n}_j \right\|^2$$
$$\text{subject to} \begin{cases} \left\langle \boldsymbol{n}'_j, \boldsymbol{l} \right\rangle \leq \alpha_{i+1} \\ -\left\langle \boldsymbol{n}'_j, \boldsymbol{l} \right\rangle \leq -\alpha_i \end{cases} \qquad (2)$$

where $\{\alpha_i\}$ are the quantized values of the shading and $\boldsymbol{n}'$ the new normal. This decomposition of the classical problems into one minimization and a set of constraints have been successfully used by Worthington and Hancock [1999] from Shape from Shading. We replace their linear equality constraints by linear inequalities. Furthermore, similarly to most of the previous work in Shape from Shading, the unit length of the resulting normal is not guarantied with such a formulation. We thus normalize the resulting vectors, and the optimization process is repeated with these new normals as initial ones.

3 Results

Our experiments were performed on a PC workstation with a 2.4 GHz Intel Core 2 Quad processor and an NVIDIA GeForce 8600-GT card. Our quadratic programming solver is implemented on GPU with a fixed number of iterations. The computing cost is linear according to the texture resolution and the number of iteration with an average of 3.6 msec for one iteration and for a 1024×1024 normal map. This shows the ability of real-time interaction of our approach.

We have experimented our approach for two main scenarios. For the first one (Figure 2), each time the user is editing the shading for a new light direction, we update the normal map by minimizing the difference with the current one taking into account the new shading. With such an approach, only one normal map is required, but only the last changes are ensured to be visually present in the resulting map. For a full user-control, we propose a second solution (Figure 3): for each new light direction, we use the minimization process to create a new normal map, and interpolate them at rendering time. Compared to [Todo et al. 2007], no complex interpolation scheme is required, while the lighting coherence between different light direction is ensure by the normal-field itself.

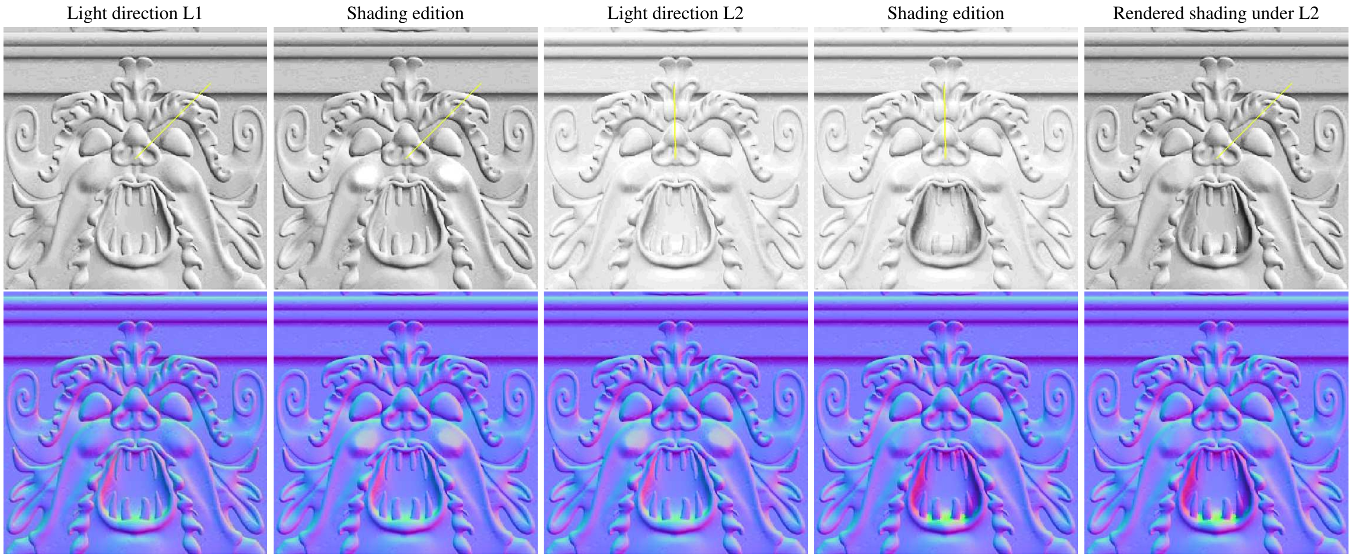

Figure 2: Accumulation mode. The first row contains the original, edited and rendered shadings. The second row contains the corresponding normal maps. In the second column, the shading on the monster's cheek is brightened under light direction L1. Then users move to light direction L2 in the third column and darken the inside of the mouth. A comparison result is shown by turn back to light direction L1.

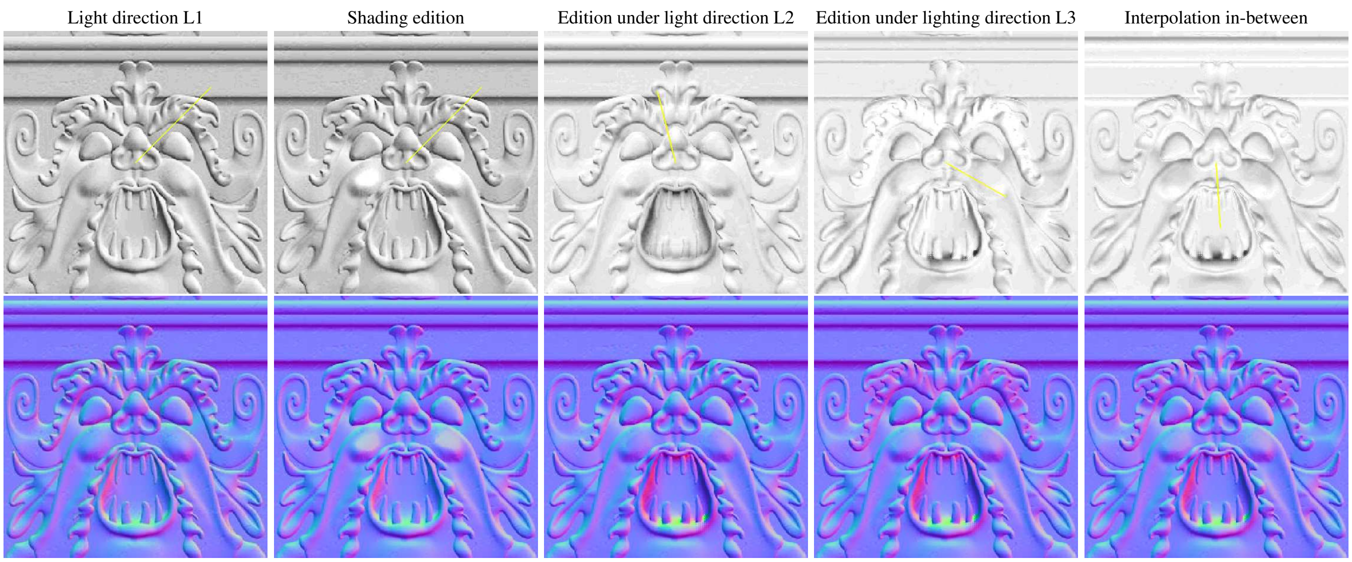

Figure 3: Interpolation mode. The first row contains the original, edited and rendered shadings. The second row contains the corresponding normal maps. The shading is modified independently under the different light directions. The resulting normal maps are interpolated at rendering time to create the corresponding shading (last column).

4 Conclusion

In this paper, we have introduced a new approach to edit normal map based on the expected shading. For this purpose, we have developed a new normal-from-shading formulation based on interval constraints. The results show that our approach is suitable to edit normal maps for a large range of shading from realistic to non-photorealistic one. We believe that our approach may be extended in future to full shape estimation and edition.

Acknowledgment

The project is supported by the INRIA Associated Team Grant named BIRD and by the National Basic research program of China (No. 2009CB320802). Xavier Granier was supported by the Open Project Program of the State Key Lab of CAD&CG (Grant No. A1007), Zhejiang University.

References

BOTSCH, M., AND SORKINE, O. 2008. On linear variational surface deformation methods. *IEEE Trans. Visualization and Computer Graphics 14*, 1, 213–230.

DALY, S. 1993. *Digital images and human vision*. MIT Press, ch. The visible differences predictor: an algorithm for the assessment of image fidelity, 179–206.

DECAUDIN, P. 1996. Cartoon Looking Rendering of 3D Scenes. Research Report 2919, INRIA, June.

TODO, H., ICHI ANJYO, K., BAXTER, W., AND IGARASHI, T. 2007. Locally controllable stylized shading. *ACM Trans. Graph. (Proc. SIGGRAPH) 26*, 3, 17.

WORTHINGTON, P. L., AND HANCOCK, E. R. 1999. New Constraints on Data-Closeness and Needle Map Consistency for Shape-from-Shading. *IEEE Trans. Pattern Analysis and Machine Intelligence 21*, 1212, 1250–1267.