# Flow-Guided Warping for Image-Based Shape Manipulation (supplemental material)

Romain Vergne<sup>1,2</sup> Pascal Barla<sup>2</sup> Georges-Pierre Bonneau<sup>1,2</sup> Roland W. Fleming<sup>3</sup> Univ. Grenoble Alpes, CNRS<sup>1</sup> Inria<sup>2</sup> Justus Liebig Universität Gießen<sup>3</sup>

# 1 Visual relationships between surface- and image-based structure tensors

A visual comparison between structure tensors is made for 2 blobby shapes and various renderings in Figures 1 and 2 (see the paper for visualizing the corresponding litspheres). The top-left images correspond to the normal map and its corresponding surface-based tensor. Other images are all renderings with their corresponding image-based tensors. Structure tensors are visualized using a combination of line integral convolution (in the direction of the maximum eigen vector) and color coding (hue corresponding to the maximum eigen vector angle, and opacity to its eigen value).



**Figure 1:** Comparison between surface-based (top-left) and image-based (the others) structure tensors for a blobby shape.

Figure 2: Same comparison with another shape.

### 2 Statistical Analysis between surface- and image-based structure tensor (shape #1)

The first shape of our data base is shown in Figure 3 where (1) is the visualization of the normal map and (2-17) are global illumination renderings, with 4 different materials (1 per column) and 4 lighting environments (1 per row). Their corresponding surface- and imagebased tensors are shown in Figure 5. Statistical relationships between maximum eigen vectors of each pair of image are summarized in Figure 4. Each entry of matrix (a) represents the averaged per-pixel dot product between vectors. Matrix (b) shows the corresponding standard deviations. Local cross-correlations between maximum eigen values are visualized in Figure 6. Matrices (a) and (b) respectively show the averaged per pixel cross-correlation and its corresponding standard deviation for each pair of tensors.



**Figure 3:** *Shape #1:* (1): normal-map; (2-17): renderings with 4 materials (dielectric, lambertian, metal, plastic) and 4 environment lightings (2 indoors and 2 outdoors.)



Figure 4: Similarity between maximum eigen vectors of each pair of tensor. Average (a) and standard deviation (b) of the per pixel dot product between eigen vectors. The global averaged dot product (for all material/lightings) for this object is 0.88 and the global standard deviation is 0.20.

**Figure 5:** *Shape #1: Visualization of surface-based tensors* (1) *and image-based tensors* (2-17)



Figure 6: Similarity between maximum eigen values of each pair of tensor. Average (a) and standard deviation (b) of the per pixel local cross correlation between eigen values. The global averaged cross correlation (for all material/lightings) for this object is 0.81 (p-value  $\ll 0.05$ ) and the global standard deviation is 0.31.

## 3 Statistical Analysis between surface- and image-based structure tensor (shape #2)

The second shape of our data base is shown in Figure 7 where (1) is the visualization of the normal map and (2-17) are global illumination renderings, with 4 different materials (1 per column) and 4 lighting environments (1 per row). Their corresponding surface- and imagebased tensors are shown in Figure 9. Statistical relationships between maximum eigen vectors of each pair of image are summarized in Figure 8. Each entry of matrix (a) represents the averaged per-pixel dot product between vectors. Matrix (b) shows the corresponding standard deviations. Local cross-correlations between maximum eigen values are visualized in Figure 10. Matrices (a) and (b) respectively show the averaged per pixel cross-correlation and its corresponding standard deviation for each pair of tensors.



**Figure 7:** *Shape #2:* (1): normal-map; (2-17): renderings with 4 materials (dielectric, lambertian, metal, plastic) and 4 environment lightings (2 indoors and 2 outdoors.)



Figure 8: Similarity between maximum eigen vectors of each pair of tensor. Average (a) and standard deviation (b) of the per pixel dot product between eigen vectors. The global averaged dot product (for all material/lightings) for this object is 0.87 and the global standard deviation is 0.21.

**Figure 9:** *Shape #2: Visualization of surface-based tensors* (1) *and image-based tensors* (2-17)



Figure 10: Similarity between maximum eigen values of each pair of tensor. Average (a) and standard deviation (b) of the per pixel local cross correlation between eigen values. The global averaged cross correlation (for all material/lightings) for this object is 0.82 (p-value  $\ll 0.05$ ) and the global standard deviation is 0.28.

## 4 Statistical Analysis between surface- and image-based structure tensor (shape #3)

The third shape of our data base is shown in Figure 11 where (1) is the visualization of the normal map and (2-17) are global illumination renderings, with 4 different materials (1 per column) and 4 lighting environments (1 per row). Their corresponding surface- and image-based tensors are shown in Figure 13. Statistical relationships between maximum eigen vectors of each pair of image are summarized in Figure 12. Each entry of matrix (a) represents the averaged per-pixel dot product between vectors. Matrix (b) shows the corresponding standard deviations. Local cross-correlations between maximum eigen values are visualized in Figure 14. Matrices (a) and (b) respectively show the averaged per pixel cross-correlation and its corresponding standard deviation for each pair of tensors.



**Figure 11:** *Shape #3:* (1): normal-map; (2-17): renderings with 4 materials (dielectric, lambertian, metal, plastic) and 4 environment lightings (2 indoors and 2 outdoors.)



Figure 12: Similarity between maximum eigen vectors of each pair of tensor. Average (a) and standard deviation (b) of the per pixel dot product between eigen vectors. The global averaged dot product (for all material/lightings) for this object is 0.86 and the global standard deviation is 0.22.

**Figure 13:** *Shape #3: Visualization of surface-based tensors* (1) *and image-based tensors* (2-17)

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Figure 14: Similarity between maximum eigen values of each pair of tensor. Average (a) and standard deviation (b) of the per pixel local cross correlation between eigen values. The global averaged cross correlation (for all material/lightings) for this object is 0.84 (p-value  $\ll 0.05$ ) and the global standard deviation is 0.21.

## 5 Statistical Analysis between surface- and image-based structure tensor (shape #4)

The fourth shape of our data base is shown in Figure 15 where (1) is the visualization of the normal map and (2-17) are global illumination renderings, with 4 different materials (1 per column) and 4 lighting environments (1 per row). Their corresponding surface- and imagebased tensors are shown in Figure 17. Statistical relationships between maximum eigen vectors of each pair of image are summarized in Figure 16. Each entry of matrix (a) represents the averaged per-pixel dot product between vectors. Matrix (b) shows the corresponding standard deviations. Local cross-correlations between maximum eigen values are visualized in Figure 18. Matrices (a) and (b) respectively show the averaged per pixel cross-correlation and its corresponding standard deviation for each pair of tensors.



**Figure 15:** *Shape #4:* (1): normal-map; (2-17): renderings with 4 materials (dielectric, lambertian, metal, plastic) and 4 environment lightings (2 indoors and 2 outdoors.)



Figure 16: Similarity between maximum eigen vectors of each pair of tensor. Average (a) and standard deviation (b) of the per pixel dot product between eigen vectors. The global averaged dot product (for all material/lightings) for this object is 0.85 and the global standard deviation is 0.23.



**Figure 17:** *Shape #4: Visualization of surface-based tensors* (1) *and image-based tensors* (2-17)



Figure 18: Similarity between maximum eigen values of each pair of tensor. Average (a) and standard deviation (b) of the per pixel local cross correlation between eigen values. The global averaged cross correlation (for all material/lightings) for this object is 0.88 (p-value  $\ll 0.05$ ) and the global standard deviation is 0.15.

# 6 Perceptual evaluation

Computer-generated renderings of the statistical analysis were used as input for experiment 1. We used the 4 shapes (cf. Figures 3,7,11,15) with 2 environment lightings (rows 1 and 2) and 2 materials (columns 2 and 3). The 9 photographs used for experiment 2 are shown in Figure 19. Before running the experiments, participants were shown an example to ensure that they understood the signification of *sharpened* and *rounded* shape. A warped version of a simple computer-generated surface (Figure 20) was shown to all participants before running experiment 1. A similar example was shown before experiment 2 but with a real photograph as input (Figure 21). Figure 22 shows the results of experiment 2 for each photograph independently. Figure 23 shows supplementary results of experiment 1, where we can observe the effect of material or lighting on the perceived sharpness.



Figure 19: Input photographs used in experiment 2.



Figure 22: Per photograph results. The x- and y-axes represent the warping amplitude and the percentage of correct answers. Error bars are standard errors of the mean according to the number of participants. Dashed lines correspond to chance level.



Figure 20: Image shown to participants before running experiment 1. From left to right: sharpened; original; rounded.



Figure 21: Image shown to participants before running experiment 2. From left to right: sharpened; original; rounded.



SB (mean: 0.75, std: 0.34) SB (mean: 0.84, std: 0.28)

**Figure 23:** Supplementary results for experiment 1. Top: per material plots. Bottom: per lighting environment plots. Imagebased (IB) and surface-based (SB) warping results are respectively shown in blue and red.