

# POSTER: Topology Maps for Anisotropic Shading

Anders Hast  
Creative Media Lab  
University of Gävle  
Kungsbäcksvägen 47  
Sweden, S-801 76, Gävle  
aht@hig.se

## ABSTRACT

There are a number of materials, like cloth, hair and brushed metal that exhibit anisotropic reflectance properties. Several illumination models have been proposed for shading of such materials. The model by Poulin and Fournier describes how hair, silk and material which can be modeled by parallel cylinders, can be rendered. It has been proposed recently how the topology for this model can vary over the surface as would be the case for many surfaces like spheres and toruses. In this paper it is described how the shading can be visually enhanced by using a map for the topology. The result will be a much more visually pleasing rendering.

## Keywords

Anisotropic shading, Varying topology, Mapping.

## 1. INTRODUCTION

There are a number of materials, like cloth [Tak04, The02], hair [Sta97, Zöc96] and brushed metal [Ash00, Ban94, War92] that exhibit anisotropic reflectance properties. Several illumination models have been proposed for shading of such materials. The model by Poulin and Fournier [Pou90] describes how material which can be modeled by parallel cylinders, can be rendered, like hair and silk. The problem with this model is that the surface is assumed to have equal topology all over the object. In Figure 1 it is obvious that real life objects exhibit a behavior where it is clearly visible that the highlight is affected by the topology of the fibers. This paper will show how such effect can be incorporated in an existing anisotropic shading model.

This is done by using a map for the topology. The result will be a much more visually pleasing rendering since the map makes it possible to vary the height of adjacent cylinders locally as would be the case for a real life object. This approach is used both for the diffuse and the specular light.

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## 2. ANISOTROPIC SHADING

Many previous models for anisotropic shading assumes that the topology of the fibers is locally flat. This is shown in figure 2 in the bottom row. It has been proposed recently [Has06] how the topology for this model can vary over the surface as would be the case for many surfaces like spheres and toruses. In the top row in the same figure it is shown how the cylinders start to climb on each other. This behavior occurs when for example a silk thread is winded around a torus or a sphere, like the balls of silk in the photo figure 1.

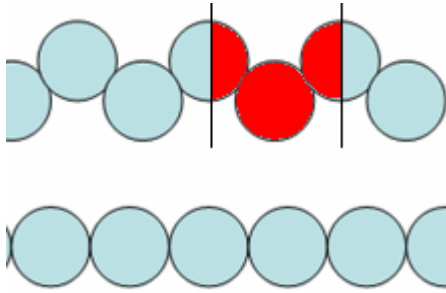


**Figure 1. A real life object where the highlight is clearly non similar because of the topology of the individual fibers.<sup>1</sup>**

The area in red is repeated along the adjacent fibers and since this part has equal height locally as its neighbors, it is possible to compute light in this area only. This method uses the shading model proposed

<sup>1</sup> This picture was taken with permission from <http://www.thecraftplace.com/>

by Poulin and Fournier, however it adds the possibility to vary the topology.



**Figure 2. The topology is assumed to be repeated and therefore it is only necessary to compute light in the red area.**

There are an infinite number of normals around each cylinder that could be used for shading. It is assumed that there are several fibers visible in each pixel. Hence, the light in a pixel can be approximated by computing the light for one fiber only. Poulin and Fournier proposed that the light contribution for a pixel should be computed by summing the light contribution by using an integral formula that is rather complex. It is possible to solve this integral for the diffuse light analytically. However, for the specular light it is necessary to use an approximation, and they propose one solution using Chebyshev polynomials and another one using a Gaussian distribution.

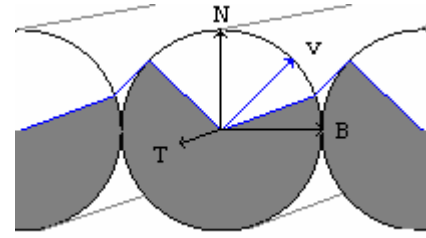
The diffuse intensity is computed by

$$I_d = \int_{\phi_1}^{\phi_2} (\mathbf{N} \cdot \mathbf{L}) \cos(\phi_E - \phi) d\phi \quad (1)$$

where the term  $\cos(\phi_E - \phi)$  is a correction factor due to the viewing position. Moreover, the intensity must be normalized by dividing by

$$\int_{\phi_1}^{\phi_2} \cos(\phi_E - \phi) d\phi \quad (2)$$

The more complex model of Poulin and Fournier takes topology of the fibers into account, like distance between fibers and hiding and shadowing, but not the climbing of fibers that is proposed in the varying topology model. If the viewer is looking at the fibers from the side, i.e. not strictly in the tangent direction, then some part of the fiber will be hidden by the fiber closer to the viewer. Similarly, the light will be shadowed by fibers, so that not the whole fiber will be lit. The fiber in the middle of figure 3 is hidden by the fiber to the right. Likewise the fiber in the middle hides the one to the left.



**Figure 3. The view vector is pointing to the right. The hiding effect is shown in the figure.**

Also note that the view vector does not have to lie in the plane spanned by the normal  $\mathbf{N}$  of the surface and the bi-tangent  $\mathbf{B}$ . Nevertheless it is possible to compute the hiding and shadowing correctly by projecting it down to that plane and perform the computations using the projected vector  $\mathbf{v}$  [Ban94]. Also note that the tangent  $\mathbf{T}$  is perpendicular to both  $\mathbf{N}$  and  $\mathbf{B}$ , and is showing the main direction of the fibers.

### 3. VARYING TOPOLOGY

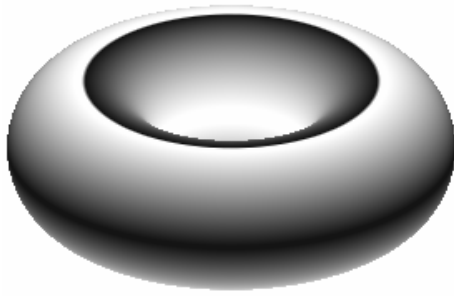
When fibers start to climb on each other, both the hiding and shadowing of the fibers will change depending on how high the adjacent fibers are compared to the fiber in question. Since it is assumed that fibers are small compared to the pixel, it is also assumed that all fibers inside a pixel behave in the same way and that the direction to the viewer and light source is constant inside the pixel. The hiding and shadowing of the whole cylinder in the middle will be taken into account when the light contribution is computed. Since the topology is assumed to be repeated, only the right part of the left cylinder is taken into account, as well as the left part of the cylinder to the right as shown in figure 2.

A torus was chosen as test object since it has an outer side that is four times longer than the inner side. Hence, the individual fibers will climb on top of each other two times from the middle of the outer side to the middle of the inner side. The Topology for the torus is shown in figure 4. The height of the cylinders to the left and right of the middle one is computed using the equation

$$H = 2 \sin \theta \quad (5)$$

where  $\theta$  varies from  $0^\circ$  to  $60^\circ$ .

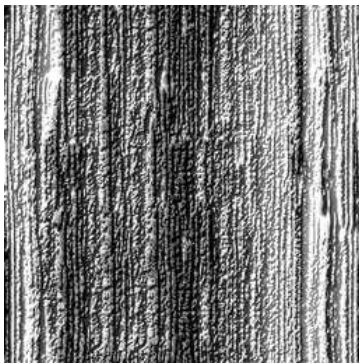
A shading value of zero corresponds to a completely flat topology. As the value increases, the fibers on the sides are being raised (or start to climb). A shading value of 1.0 means the same thing as a shading value of zero, i.e. the fibers on the sides are as close together as possible, i.e. completely adjacent.



**Figure 4. The shading value corresponds to the topology of the fibers on the torus.**

#### 4. TOPOLOGY MAPS

The topology can be varied in many ways. In this paper a map was used to make the object appear more real life and not so synthetically smooth. There are many ways to do this. The mathematical topology shown in figure 4 can be changed by adding some noise or adding a regular pattern. Such pattern can be stored in a map and figure 5 shows a map that was chosen for the final renderings. This map is actually a bump map where the height values were scaled down to fit the purpose of being used as a topology map. Actually both the pattern and the mathematical topology can be stored together in one single map, but it was chosen herein to keep them separate. Hence it is possible to distinguish between the two and to choose what kind of perturbation of the mathematical topology we actually want for each case. Different maps were tested, nevertheless, this map gave a quite convincing result.



**Figure 5. Topology map.<sup>2</sup>**

Figure 6 and 7 compares different anisotropic shading techniques under two different lighting conditions. In the top the fast method (Banks) is used where the maximum light is computed. The next row shows the result of the method of Poulin and Fournier

<sup>2</sup> The map used was a free bump map found at <http://www.m3corp.com/>

where the integral is sampled. The next row shows the varying topology method and finally the last row shows the varying topology method using maps. Note that the varying topology method produces different shadings than the fast method and the Poulin and Fournier method.

The blending of the mathematical topology and the map can be done in many ways. In the renderings the map was scaled so that it was in the range from -0.25 to +0.25. This height was added to the mathematical height and then the result was truncated in the range 0 to  $\sqrt{3}$ . The total computation was made very simple in this way. For non parametrical objects, i.e. arbitrary polygon objects, it might be necessary to not use a mathematical topology, since it is not always possible to derive it. For these types of objects it is preferable to store the actual topology in the map.

When a map is used it is clear that the shading, especially the highlight, is not so mathematically smooth anymore. It resembles more a real-life object as the ones shown in figure 1. It should be noted that the individual fibers are still assumed to be very small, so that several fibers are visible per pixel.

#### 5. CONCLUSIONS AND FUTURE WORK

This method produces in a very simple way more naturally looking renderings of anisotropic materials. The extra amount of work needed is relatively small compared to the amount of work needed for the varying topology approach in general.

For future work it is proposed that this approach should be investigated further and perhaps a real-time application is possible.

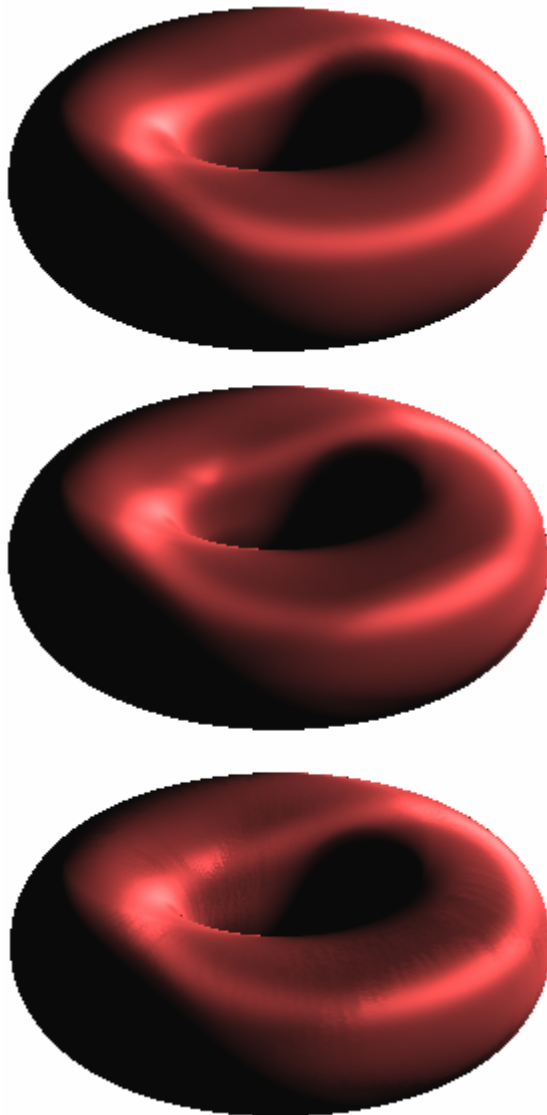
Furthermore, it should be investigated how different level of details can be used so that close ups can be rendered using bump mapping where individual fibers are visible and the map method can be used on larger distances. It should be investigated how a smooth transition between these two LOD's can be performed.

#### 6. REFERENCES

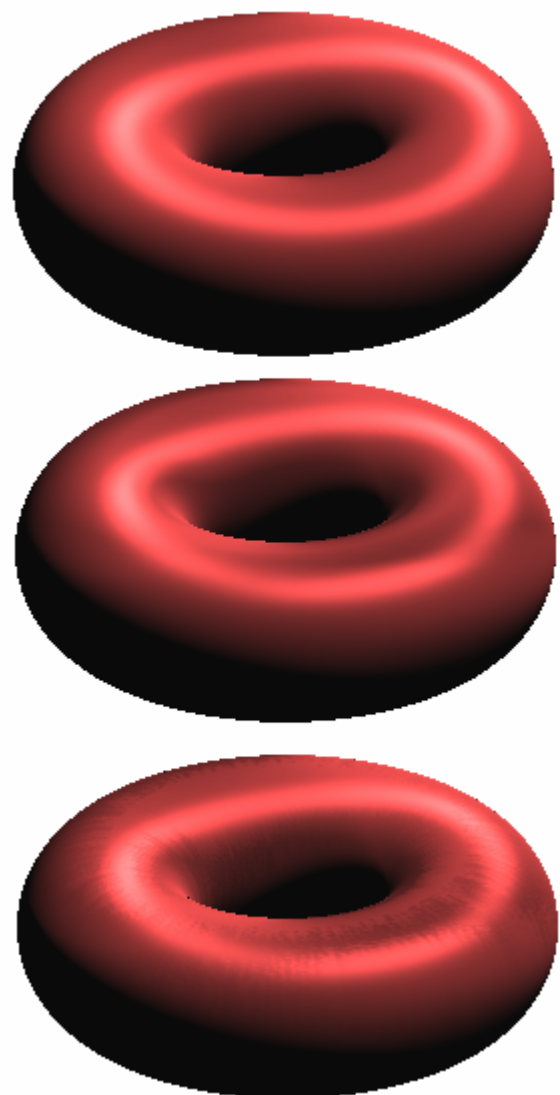
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**Figure 5. Different anisotropic shading methods. From top to bottom: Poulin and Fournier, Varying topology and Varying topology using a map.**



**Figure 6. Different anisotropic shading methods. From top to bottom: Poulin and Fournier, Varying topology and Varying topology using a map.**