# Procedural Approach for Realistic Woven Fabric Rendering

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**Abstract**

*We present a new procedural method for photorealistic rendering of woven fabric material. The goal of our research is to provide a new procedural method that renders photorealistic woven fabric without any measured data. The proposed method models the reflectance properties of woven fabric with alternating anisotropy and yarn-level surface normal manipulation. The experimental results show the proposed method can be successfully applied to photorealistic rendering of diverse woven fabric materials.*

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Rendering, Global Illumination

## 1. Introduction

Fabric appearance is important in industrial applications of computer graphics in the textile, garment, and fabric care industries. There are two main types of fabrics namely, *knitwear* and *woven* fabrics. Our goal is to produce photo-realistic images of woven fabrics without any material data such as the measured BRDFs (Fig. 1 (a)) or BTFs.

(a) Measured BRDF (34 Mb) (b) Our approach

**Figure 1:** *Comparison with the isotropic measured BRDF.*

**Measured data-based methods.** Sattler et al. measured, stored, and retrieved bidirectional texture function (BTF) data as needed to render clothes [SSK03]. Wang et al. introduced a method for the visual modeling of spatially-varying anisotropic reflectance using fabric data, such as satin and velvet captured from simple acquisition device [WZT*08]. However, these methods required a lot of time for material measurements and large storage space.

**Texel-based methods.** Xu et al. introduced the idea to define a volumetric structure specifically for yarn called the *lumislice* [XCL*01]. However, these methods cannot be applied to woven fabrics due to the different characteristics of threads and weave pattern.

**Weave pattern-based methods.** Adabala et al. presented a technique based on a microfacet model and procedural textures that is capable of rendering fabrics with a variety of weave patterns at different level of detail [AMTF03]. Unfortunately, this method focuses on variety of weave patterns and treated the light reflection on the yarn surface somewhat lightly. In this paper, we present a procedural approach for realistic woven fabric rendering with alternating anisotropy and yarn-level surface normal manipulation.

## 2. Algorithm Overview

Woven fabric is constructed by interlacing two sets of parallel threads, known as *warp* and *weft*. Each weave element is a building block of woven fabric, and both weft yarn and warp yarn are included in each element. The pattern in which the warp and weft are interleaved varies greatly, but the majority of woven fabrics are made in one of the three simplest weave patterns: *plain*, *twill* and *satin* weave. In our work, we deal with those weave patterns for realistic fabric rendering.

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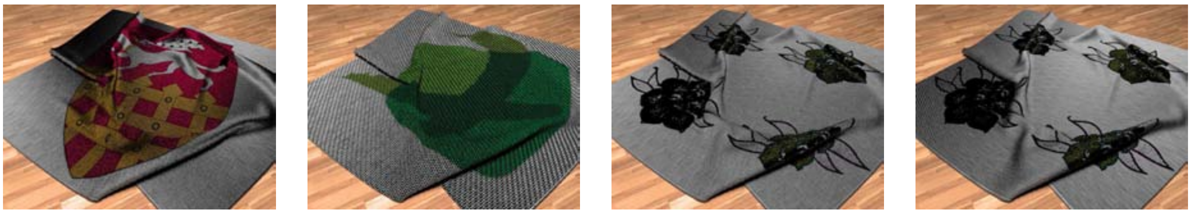

(a) anisotropic reflectance (b) weave-based bump mapping (c) twill weave (d) satin weave

**Figure 2:** *Renderings produced by our approach: (a) $e_x = 100$, $e_y = 2$, (b) The yarn curvature ($c_y$) is set to be 0.75, (c) $(i, j, k)$ = (1,2,1), (d) $(i, j, k)$ = (9,1,3)*

To provide realistic rendering for woven fabrics, we describe the key characteristics of woven fabrics as follows:

- **Anisotropic reflectance:** Because the yarns are oriented in different directions, the reflectance anisotropy is alternating according to the *yarn direction*.
- **Bumpy surface:** In order to produce realistic bumpy surface caused by woven structure, we devised a *weave-based* bump mapping technique.
- **Spatially-varying appearance:** For woven fabric, the noise should smoothly change along one single yarn while it should be discontinuous between adjacent yarns.

Based on these characteristics we use a BRDF microfacet model based on the weave pattern. This microfacet model takes the approach proposed by Ashikhmin and Shirley to represent anisotropic reflectance of woven fabric surface as follows:

$$D(\omega_h) = \frac{\sqrt{(e_x+1)(e_y+1)}}{2\pi}(\omega_h \cdot \mathbf{n})^{e_x \cos^2\phi + e_y \sin^2\phi} \quad (1)$$

where $e_x$ and $e_y$ are the exponents for the distribution function for controlling the anisotropy of the reflectance, and $\phi$ denotes the azimuthal angle of the half vector $\omega_h$. First, in order to alternate the anisotropy, we determine whether the sampled point is warp, weft, or inter-yarn gap. This can be easily determined by computing the determinant $\mathbf{d}$ as follows:

$$\mathbf{d} = \left(\left\lfloor \frac{u}{n} \right\rfloor \mathbf{mod}\ i + j\left(\left\lfloor \frac{v}{m} \right\rfloor \mathbf{mod}\ k\right)\right) \mathbf{mod}\ (i+j) \quad (2)$$

where $n$ and $m$ denote the length of the weave element in $u$, $v$ direction respectively. The parameter $i$ and $j$ are the number of continuous weft and warp elements in a single weave row respectively. $k$ is the number of element shifts in the next weave row. If the determinant $\mathbf{d}$ is less than $i$, the sampled point is located within a weft element. Otherwise it is within a warp element. Then we apply different distribution functions $D_p(\omega_h)$ and $D_t(\omega_h)$ for warp yarns and weft yarns respectively. Our implementation of the weave-based bump mapping is based on finding an approximation to the partial derivatives $\partial\mathbf{p}/\partial u$ and $\partial\mathbf{p}/\partial v$ of the displaced surface and using them in place of the surface's actual partial derivatives to compute the shading normal. The point $\mathbf{p}$ denotes a sampled point on a given geometry for woven fabric. The yarn cross section is flat when the *yarn curvature* ($c_y$) is 0, and the yarn is circular when $c_y$ is 1.0. Finally, to represent the spatially varying surface appearance with enhanced realism of woven fabrics, we employed the *Perlin* noise for irregularity.

## 3. Results

We have implemented our algorithms on a PC running Windows XP with Intel Xeon 3.0GHz Quad-core dual CPUs, 8 GB memory and an NVIDIA QuadroFX 5600 GPU. To generate the images we applied the proposed algorithm to cloth models (Fig. 1) which consist of 15,415 triangles obtained from the *Maya nCloth* plug-in. We have rendered test images (640×480) by performing bidirectional path tracing with 1024 samples per pixel. In order to verify the rendering quality of our method, we performed the rendering of four different woven fabrics as shown in Fig. 2. The *alternating anisotropy* generates the spatially varying reflectance of woven fabric (a), and the weave-based bump mapping drastically increases the realism (b). Furthermore, our approach can represent various woven fabrics such as twill (1,2,1) (c) and satin (9,1,3) (d) by controlling the weave patterns.

## 4. Conclusion

We have presented a procedural approach to realistic woven fabric rendering. One of the principal benefits of our approach is that it procedurally modeled the woven surface reflection and requires no data such as measured BRDFs or BTFs. The results demonstrate that our method can be successfully employed for realistic rendering of diverse woven fabric materials.

## References

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