Proceedings of the Fifth IIEEJ International Workshop
on Image Electronics and Visual Computing 2017
Da Nang, Vietnam, February 28- March 3, 2017

A RECURSIVE PROCEDURAL MODEL FOR IMPROVING APPEARANCE OF CLOTHES WITH FIBER-LEVEL DETAILS

Yasunari Ikeda Issei Fujishiro
Keio University

ABSTRACT

Making realistic yarn objects, a common material for textile, without losing details is a challenging issue. Recent methods for modeling yarn can be classified into two categories: volume-based methods and fiber-based ones. Among them, one of the latest fiber-based methods attempts to reconstruct twisted fibers from CT (Computed Tomography) images to improve the details of yarn models. While this method dramatically improves the details, mainly because of the limited resolution of the CT scanner, the fluff and fuzz of the yarn still cannot be obtained. Our goal is to realize the fluff and fuzz of yarn. To that end, we developed an extension method to attach microfibers to each fiber of the yarn. The method approximates the distribution of microfibers by recursively using statistical data. In this paper, we discuss the preliminary design of the method.

1. INTRODUCTION

The rendering of humans in the virtual world has been improved by a huge number of studies. Hair, eyes, skins and their motions have been important research topics in computer graphics for decades. In addition, clothes also have been a common research topic in virtual human. Clothes are generally made of textile, which itself can be regarded as an aggregation of fibers. In this context, rendering textile by using yarn-based models with fiber-level details remains challenging.

Zhao et al. made a new framework [11] to procedurally construct yarns with twenty-two parameters stemming from statistical data obtained from CT images. At the same time, they explained the difficulty of making textile by referring to it's structural and optical complexities, which result in drastic changes in their appearance depending on the situation. Even though Zhao's framework made a crucial contribution to improving details of yarn models, fuzz and fluff of the yarns still cannot be detected because of the limited sampling rate of the CT scanner.

2. RELATED WORK

We have to address several problems to use microstructure in computer graphics. The features of microstructures such as a surface of metals, clays, or brushed glasses cannot be detected sufficiently with conventional sampling schemes, as it would take a very long time. During animation, highly detailed surfaces will appear to flicker—a phenomenon known as "flickering"—and the details of the object become difficult to grasp. To tackle the microstructure problems and improve the appearance of virtual objects, several methods have been proposed, which can be separated into microfacet, volume, or geometric-based methods. The brief introduction to each category will be explained in the following paragraphs.

Microfacet methods are one of the most famous approaches to represent microstructures. Firstly microfacet effects were found in a physics field from an experimental study [4], and the same research group derived a theoretical model of this effect [5]. Microfacet models were introduced to computer graphics by Blinn [2], and Cook and Torrance modified these models to apply them to common computer graphics [10]. Microfacet models simulate the distribution of normal vectors in the microsurfaces and calculate the total brightness of each of the areas. These models are applicable to cloth rendering. Indeed, Wang et al. used microfacet theory to simulate an anisotropic effect [3].

Volume-based methods define a density distribution of yarn. Zhao's method [12] using CT scanner uses scanned data as a small patch of fibers. Then, this method puts the patches on the surface of the target cloth, and consequently the resulting cloth appears to have realistic fluff. They scanned a density distribution of sample yarns and created a small database of fabrics, which is used in the synthesis step. This method can simulate woven clothes with fiber level details relevant to a target pattern from the database. In addition, the relationship between weave patterns and specular reflections was also analyzed in 2012 [8]. Although these methods contributed to improving the appearance of yarn objects, it was difficult to fiddle with the parameters and the yarn appearance.

In contrast, traditional fiber-based methods reconstruct yarn as a bunch of fibers with patch-level detail. To generate a realistic cloth with fiber level details, Khungurn derived a fiber-based scattering model [9]. This study made a robust scattering model and clearly indicated the importance of using the model. The next problem of making clothes is to make the parameters related to yarns adjustable. Because of many parameters of yarn objects, the flexibility of previous cloth objects is not enough from the viewpoint of the parameter fitting. One of the latest fiber-based methods [11] realized reconstructions of yarn with fiber-level detail and made possible the procedural modeling of yarn. More specifically, this method allowed a user to obtain twenty-two parameters from CT scanned images of yarn, and made it easy to change the parameters of yarn objects such as length, the number of fibers, twisting or distribution of flyaway fibers.

However, the fluff of the yarn is oversimplified in the method because of the thickness of thin flyaway fibers and limited sampling rate of the CT scanner. We can see the effect of this oversimplified flyaway fibers in previous research. They compare the resulting images generated by their method with original photographs. The resulting images of yarns with few flyaway fibers are quite similar to a corresponding photograph. However, the resulting images of yarns with many flyaway fibers are not the case; the brightness of real yarn is higher than that of the generated one. In this research, in order to attach fuzz to yarn objects, we refer to the above fiber-based method and recursively reuse their parameters to generate more realistic microfibers.

3. ALGORITHM

To tackle the sampling rate issue of CT scanner, we assume that the yarn object has a fractal structure. Fractal is a well-known structure; it can be found in nature, e.g. leaves, rivers, and branches of trees. Based on this assumption, we attached additional thin fibers to the yarn object, which can be generated by the previous method, and we called this additional fibers microfibers, in order to avoid confusion.

A yarn object made by the previous method has regular and flyaway fibers. In contrast to regular fibers which are spatially aligned, flyaway fibers are irregularly oriented. These flyaway fibers are the fibers which were cut or drawn out. In addition, flyaway fibers can be classified into two categories—loop and hair-type flyaway fibers. Loop-type flyaway fibers have two endpoints that fit into the yarn object (imagine a solar prominence). On the other hand, hair-type flyaway fibers have one endpoint fitting into the yarn object. In the previous method, these fibers are additionally created after the creation of regular and loop-type flyaway fibers.

While referring to the reconstruction framework of the previous method, our method adds microfibers for each of the fibers. In this method, we assume that local features of fibers are fractally recurring. Thus, we use parameters of flyaway fibers to create microfibers. The position of each microfiber depends on the density distribution from CT images. In addition, the length of each microfiber is determined based on the ratio of length between original yarns and flyaway fibers and can be modified with an additional weight defined by users.

As a result of our approach, it is expected that microstructure of yarn objects can be seen in an enlarged view. The details of our algorithm will be presented in the following sections.

3.1. ORIGINAL FRAMEWORK

There are four main steps to generate yarns and obtain its parameters in Zhao's original method.

1. Obtain plies (bunch of fibers) statistical data from CT scanned images
2. Obtain fibers statistical data from ply data
3. Generate plies with fibers from statistical data
4. Generate yarns with generated plies

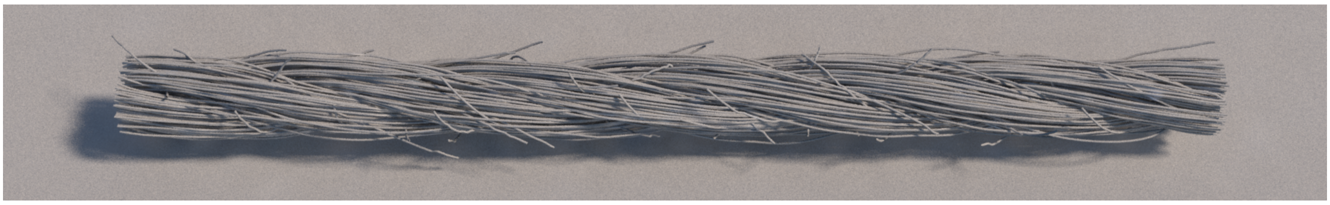
In the first step, CT scanned fibers were separated into each ply by using k-means clustering, where k is defined as the number of real plies. After that, the system combines cross-sectional fiber distribution in depth and reconstructs each fiber.

The second step focuses on the fiber-level statistical data. Firstly, fibers are separated into flyaway fibers and regular fibers depending on the distance between the positions of fibers and the center of each ply. If the distance is too long, the fiber will be classified as a flyaway fiber. After the separation process, statistical data will be obtained from both types of fibers. There are several obtained parameters, i.e., the numbers of hair-type flyaway fibers, the numbers of loop-type flyaway fibers, the numbers of general fibers, twisting angle of rotation, and radius of each ply.

The third and fourth steps are the generation process. This framework generates fibers from statistical data and combines them to make each ply, and after that, the last step merges plies into a single yarn. This is the framework of the original method proposed by Zhao. In this research, we modify the fourth step because we can use all the statistical parameters obtained from the source fibers. In addition, flyaway fibers which are the target objects of the added microfibers are already generated by the fourth step. The details of making microfibers will be explained in the following sections.

3.2. DENSITY

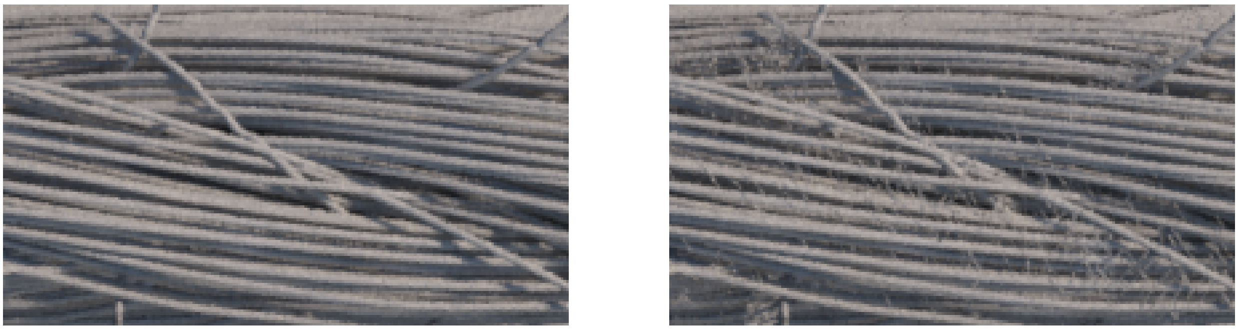
To define the density of microfibers, the method uses the number of flyaway fibers on each ply. As we mentioned before, it is assumed that the statistical data can be recursively



(a) The rendered image with the original method in [11].

(b) The rendered image with our method.

Figure 1: Rendered images.



(a) The rendered image with the original method in [11]. (b) The rendered image with our method.

Figure 2: Rendered images with enlarged view.

used to generate microfibers. The numbers of loop-type and hair-type flyaway fibers are already obtained during the second step. Therefore, we use the total number of flyaway fibers as the number of microfibers on each fiber. The positions of microfibers are randomly chosen from vertices on each fiber.

3.3. ROTATION

The rotation angles of the microfibers are also defined from the statistical data. Each flyaway fiber is described by a rotation angle and fiber length. The rotation angle will be adjusted. The length of each microfiber can be modified manually because obtained length from flyaway fibers is too long to apply to microfibers.

4. RESULT

All images in this paper are rendered on a standard high-end PC (CPU: Intel Core-i7 6700HQ 2.6GHz, GPU: NVIDIA GeForce GTX 960M, RAM: 16GB) by using Mitsuba renderer with Photon mapper [13]. The statistical data for making microfibers are obtained by CT images, which were taken by Zhao and his research team. Comparing **Fig. 1(b)** with **Fig. 1(a)**, we can see the image with our method has some blur effect at the edge of fibers and shows a darker shadow thanks to the obtained microfibers. On the other hand, comparing **Fig. 2(b)** with **Fig. 2(a)**, it turns out that the microfibers can hide the shadows among fibers, as a result the overall color of the yarn is lighter than that with the previous method. From this result, it is recognized that one of the important elements of softness effect with fluff and fuzz is the area of hidden fibers.

5. CONCLUDING NOTES

In this work, we attached microfibers by using yarn statistical data and successfully added the new feature. It is expected that the appearance of aged, moth-eaten or wet clothes will be improved even more.

However, the position, length, and thickness of microfibers are not accurate. The parameters are recursively used, and some of them are modified, such as the length of microfibers. To address these problems, it is necessary to precisely analyze the features of real microfibers and quantify them.

Moreover, while fabric consists of a bunch of yarns, our method focuses only on the details of a single yarn. Thus, a new framework is necessary to knit fabrics with our yarn model. Additionally, it is required to consider collision detection among microfibers. Currently, it is not considered in this method, and as such microfibers are intersecting each other. Collision detection warrants to consider static electricity, dirt, and softness of clothes. Collision detection among microstructure still remains as an important issue in the computer graphics field. Recent hair simulation methods [6, 7] have aimed to solve this complex problem. However, fiber–fiber collision detection cannot be solved by current manner. Therefore a new method to solve volume–volume or microstructure–microstructure collision detection is needed for the future. To clarify the elements of softness effects with fluff and fuzz is one of the most important issues of cloth research. We found that the shielding effects of microfibers are important to realize the softness effect. A similar idea is already known in the microfacet theory as *masking function* [1]. Microstructures have quite small irregularity on their surfaces. Therefore, some incident light rays and reflected light rays will be shielded by these small irregularities. To make a more realistic geometric model of yarn objects, it is necessary to simulate this shielding effect.

ACKNOWLEDGEMENTS

We are grateful to Shuang Zhao, Fujun Luan, and Kavita Bala for publishing the source code and CT images of their study [11]. The source code helped us improve the algorithm and output the images of the study.

This research presentation is supported in part by a research assistantship of a Grant-in-Aid to the Program for Leading Graduate School for “Science for Development of Super Mature Society” from MEXT in Japan.

REFERENCES

[1] B. Smith: “Geometrical Shadowing of a Randomly Rough Surface,” IEEE Transactions on Antennas and Propagation, Vol. 15, No. 5, pp. 668-671 (1967). DOI: 10.1109/TAP.1967.1138991

[2] J. F. Blinn: “Models of Light Reflection for Computer Synthesized Pictures,” ACM SIGGRAPH Computer Graphics, Vol. 11, No. 2, pp. 192-198 (1977). DOI: 10.1145/965141.563893

[3] J. Wang, S. Zhao, X. Tong, J. Snyder, and B. Guo: “Modeling Anisotropic Surface Reflectance with Example-Based Microfacet Synthesis,” ACM Transactions on Graphics, Vol. 27, No. 3, pp. 41:1–41:9 (2008). DOI: 10.1145/1360612.1360640

[4] K. E. Torrance, E. M. Sparrow, and R. C. Birkebak: “Polarization, Directional Distribution, and Off-Specular Peak Phenomena in Light Reflected from Roughened Surfaces,” Journal of the Optical Society of America, Vol. 56, No. 7, pp. 916–925 (1966). DOI: 10.1364/JOSA.56.000916

[5] K. E. Torrance and E. M. Sparrow: “Theory for Off-Specular Reflection From Roughened Surfaces,” Journal of the Optical Society of America, Vol. 57, No. 9, pp. 1105–1114 (1967). DOI: 10.1364/JOSA.57.001105

[6] M. Chai, C. Zheng, and K. Zhou: “A Reduced Model for Interactive Hairs,” ACM Transactions on Graphics, Vol. 33, No. 4, pp. 124:1–124:11 (2014). DOI: 10.1145/2601097.2601211

[7] M. Chai, C. Zheng, and K. Zhou: “Adaptive Skinning for Interactive Hair-Solid Simulation,” IEEE Transactions on Visualization and Computer Graphics. DOI: 10.1109/TVCG.2016.2551242 (To appear)

[8] P. Irawan and S. Marschner: “Specular Reflection from Woven Cloth,” ACM Transactions on Graphics, Vol. 31, No. 1, pp. 11:1–11:20 (2012). DOI: 10.1145/2077341.2077352

[9] P. Khungurn, D. Schroeder, S. Zhao, K. Bala, and S. Marschner: “Matching Real Fabrics with Micro-Appearance Models,” ACM Transactions on Graphics, Vol. 35, No. 1, pp. 1:1–1:26 (2015). DOI: 10.1145/2818648

[10] R. L. Cook and K. E. Torrance: “A Reflectance Model for Computer Graphics,” ACM Transactions on Graphics, Vol. 1, No. 1, pp. 7-24 (1982). DOI: 10.1145/357290.357293

[11] S. Zhao, F. Luan, and K. Bala: “Fitting Procedural Yarn Models for Realistic Cloth Rendering,” ACM Transactions on Graphics, Vol. 35, No. 4, pp. 51:1–51:11 (2016). DOI: 10.1145/2897824.2925932

[12] S. Zhao, W. Jakob, S. Marschner, and K. Bala: “Structure-Aware Synthesis for Predictive Woven Fabric Appearance,” ACM Transactions on Graphics, Vol. 31, No. 4, pp. 75:1–75:10 (2012). DOI: 10.1145/2185520.2185571

[13] W. Jakob: Mitsuba Renderer. http://www.mitsuba-renderer.org (2010).