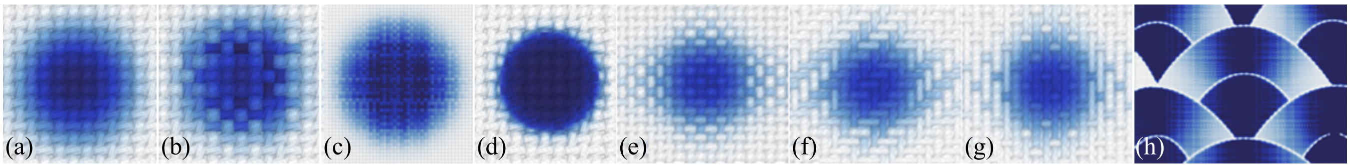
Dyeing Theory based Liquid Diffusion Model on Woven Cloth

Y. Morimoto * Kyushu University

M. Tanaka † The University of Tokyo

R. Tsuruno ‡ Kyushu University

K. Tomimatsu § Kyushu University



1 Introduction

This paper describes a method for simulating and visualizing dyeing based on weave patterns and the physical parameters of the threads and the dye. We apply Fick's second law with a variable diffusion coefficient. Visual simulation of dyeing is important for representing garments in computer graphics images and it is also important as a drawing simulation. The liquid penetration into cloth is a complicated phenomenon from both a scientific and a physical standpoint. The pattern and color of dyed cloth is a function of the physical properties of the dye and the fabric. It is a different phenomenon from liquid diffusion on a paper. Some characteristic features of liquid diffusion on a cloth that are influenced by weave patterns, such as thin spots and mottles. In an actual dyeing, wet cloth is used for preventing color heterogeneity, so this paper presents the dyeing system on wet cloth. The results obtained using our model demonstrate that it is capable of modeling many of the characteristics of dyeing.

2 Our Method

Cloth Model: We represent the cloth by cells. We define two kinds of cells, namely a cloth cell, and a diffusion cell. In cloth cells, parameters such as the weft or warp, the vertical position relative to the weave patterns, the size of threads and gaps, and other physical diffusion factors specific for each thread are defined. Each cloth cell is subdivided into several diffusion cells and diffusion cells are then used to calculate the diffusion.

Dye Diffusion Model: We discretize diffusion equation to obtain

$$\frac{\Delta\phi_i}{\Delta t} = \frac{1}{\Delta d}\left\{D_{i+\frac{1}{2}}\frac{\phi_{i+1}-\phi_i}{\Delta d} + D_{i-\frac{1}{2}}\frac{\phi_{i-1}-\phi_i}{\Delta d}\right\} \tag{1}$$

where Φ is the diffusion density, i is the x-axis of the diffusion cells, Δd is the distance interval. This equation is represented in a one-dimentional form. In our model, 4 neighboring diffusion cells in the same layer and a neighboring diffusion cell in the other layer are used to calculate dye diffusion. D is defined as the diffusion coefficient between diffusion cells by Weisz-Zollinger model [S.-H. August 1997] and it is calculated with tourtuosity T, porosity P, diffusion coefficient in free the water D_0, and Φ. D_0 is the diffusion coefficient in free water and is calculated according to [van den 1994]. P is defined as the ratio of void volume in a thread fiber. T denotes the degree of twist such that the smaller the value of the tortuosity is, the bigger the twist is. We define three kinds of tortuosity in our method: one is the twist of the thread (τ_1), another is the position of a thread, including its orientation in the weave pattern (τ_2), the other is from the different orientations of fibers in neighboring diffusion cells (τ_3). τ_3 has five different conditions (I: different layer, II: two fibers are in the same layer, and are connected to each other perpendicularly,, III: fiber and gap, IV: gap and gap, V: fiber and fiber in the same layer, and are connected to each other in same direction as the fiber axis) which depend on properties such as the layer neighboring diffusion cells are in and their porosity. Finally, the tortuosity of a cell T between diffusion cells is defined as ($T = \tau_1\tau_2\tau_3$). We present the way to produce a dyeing pattern with the total amount of dye in a diffusion cell V. We calculate V from another parameter B that denotes the volume ratio in the range (0, 1]. B is based on the normalized average RGB values in an image.

Visualization: Applying the algorithm of dye diffusion model gives the dye dispersion. The algorithm can be used to determine the basic color of the diffusion pixels. We decide the basic colors by applying linear interpolation to the highest and lowest color values of a real image of a dyed cloth. Finally, the texture of the cloth is multiplied by the color of the dye. We use the method that determines the cloth's texture by mapping the texture using the yarn's shadow [Adabala 2003].

3 Result

The results of our simulation are shown in Figure while Table gives the parameters used. Some thin colored threads can clearly be seen in (c), mottles can be seen in (e). From the comparison between (a) and (b), we find that P has more effect on the final appearance than τ_1. (f)(g) shows the effect of different kinds of weave patterns (f: diagonal weave, g: satin weave) having identical parameters on dye diffusion. There are obvious differences in the patterns obtained for different weave patterns. (h) shows a result of simulations for simple dyeing techniques. The image input for B can represent patterns by preventing diffusion that have never been considered in previous studies.

Common factors						
size of threads, gaps	8, 2 (pixels) (4, 1 in c,h)					
$D_0, \Delta t$	1.93 (mm^2/h), 0.0005 (h)					
$\Delta d, \tau_2, IV$	0.05 (mm), 0.47, 1 (ratio)					
dye destribution	circle with 30 (pixels) (except for h)					
initial amount of dye	1.0V					
the number of DC	200*200*2 (800*600*2 in h)					
Others	I	II	III	V	τ_1	P
a	1	1	0	1	.5r	.5
bch	1	1	0	1	1	.5r
d	0	.05	1	0	1	.5
efg	.01	.01	.01	1	1	.5

Table 1: Properties from images. r is a random value in (.5, 1].

References

ADABALA, N. 2003. A procedural thread texture model. 33–40.

S.-H., B. August 1997. Diffusion/adsorption behaviour of reactive dyes in cellulose. *Dyes and Pigments 34*, 321–340(20).

VAN DEN, B. R. 1994. Human exposure to soil contamination: a qualitative and quantitative analysis towards proposals for human toxicological intervention values (partly revised edition). *RIVM Rapport 725201011*.

*e-mail: reo@verygood.aid.design.kyushu-u.ac.jp

†e-mail: tanaka@mps.q.t.u-tokyo.ac.jp

‡e-mail:tsuruno@design.kyushu-u.ac.jp

§e-mail:tomimatu@design.kyushu-u.ac.jp