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Research on optical simulation system for halftone printing dot with Monte Carlo method

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ABSTRACT

The optical simulation system of printing dot is proposed, which could promote optical study of printing dots properties and improve printing quality. The optical simulation system was built based on Monte Carlo program that can simulate photons propagation path in paper. Once inputting the optical parameters of paper and ink, the optical dot simulation program will simulate millions of photons propagation path in prints. After analyzing statistical information of photons, dot morphology and dot reflective data can be obtained. The results showed that simulation system is versatile and easy to operate, besides the simulated dot shape and reflectance quite approached to realistic printing condition. The optical simulation system could sufficiently accomplish printing dot optical properties simulation, which provides a new way to predict and control printing quality.

1. Introduction

Prints are one of the most commonly used spreading media. When people see printing picture and generate color sense in brain, two basic conditions must be involved. One is vision system and the other is light. The optical properties of prints decide color sense under the same light condition. Prints consist of printing ink and printing material [1]. Ink covered on the printing material not distribute as continuous tone, but separately distribute as printing dot. The condition of printing dot largely decide printing quality. Printing dots attributes such as dot shape, dot size and distribute state are the results of halftone screening process. Only through screening process, then the origin image could be printed. Until now frequency and amplitude modulated screening are two commonly used screening methods. No matter which method is adopted, optical dot gain phenomenon could not be avoided. The definition of printing dot gain is that percentage of dot area on prints is larger than that of dot area on printing plate, which is mainly caused by light scattering [2]. With deep relevant studies, light scattering has been becoming an unavoidable factor in building printing models. The first printing model is Murray-Davies model that was only take reflection into consideration [3]. In order to improve reflectance model accuracy, Yule and Nielsen introduced amendment parameter N and established Clapper-Yule model [4,5]. After that several different reflectance model have been built such as Kubelka-Munk model [6], PSF model and DOTR2002 model [7,8]. Each model has its own superiority and increase reflectance accuracy to some extent. Not until Monte Carlo method was introduced into printing model area, reflectance model has been improved largely. That is because Monte-Carlo method could substantially reflect prints attributes. Robert Beuc successfully accomplished paper surface simulation based on Monte-Carlo theory in 2009 [9]. Then Damir Modric researched the spectral property of printing paper in 2012 [10]. Furthermore, Qi Wang established a

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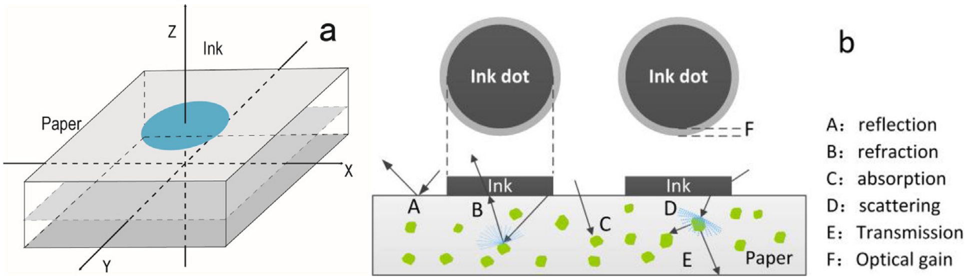

Fig. 1. The illustration of printing dot (a) single dot (b) interaction between light and prints.

new reflectance prediction model with Monte Carlo method in 2016 [11]. That attempts all strongly push forward printing reflectance model studies.

This paper mainly research and establish an optical simulation system of printing dots based on Monte-Carlo method. That optical system can simulate most optical characters of printing dot such as dot reflectance value, dot size and dot shape, which could promote optical study of printing dots characters and improve printing quality.

2. The Monte-Carlo optical simulation system

Monte-Carlo method originates from statistics which could also be called stochastic method. This method was widely used in medical sciences, finance and optics fields [12,13]. When it comes to deal with complicated problem, the Monte Carlo is often used because of its flexible character. Printing is one kind of multilayer material that consists of paper and ink. Fig. 1 (a) illustrates the printing dot structure that paper serve as support material and ink separately distribute on it. Paper usually is composed of fiber and filler. The fiber morphology and filler quality heavily affect the roughness of paper surface. Besides, the ink permeability also has influence on prints optical character. How light propagate or spread is a comprehensive process which cannot be described in certain way [14]. According to the path of light propagates in paper, various optical phenomenon occur. That includes reflection, transmission, scattering. Fig. 1 (b) show the detail of light spreading result. Among them the special property is optical gain illustrated by Fig. 1(b) F area. While light hit the surface, photons have two choices to come into prints that either form ink area or blank area, which is the same to getting out process. There are a small percent of photons will get into prints form ink area and come out from blank area. It is this small fraction of photons that cause optical dot gain [15]. As photons moving track is stochastic, it is pretty appropriate to take advantage of Monte Carlo method to study prints optical characters.

The primary steps describing photon track in prints include creating the propagation distance, changing photon directions and recording the variation of photon energy. By these three steps, how photons move in paper and which geometrical optics phenomenon it occurs can be described comprehensively. Generating the distance of photon move is the first procedure. Photon move distance which is shot to stepsize is a random variable depending on scattering coefficient and absorption coefficient [16]. The stepsize of photon move follow Beer law shown by formula (1), where σ_α, σ_s separately represent as absorption and scattering index.

$$s = \frac{-\ln\varepsilon}{\sigma_a + \sigma_s} \tag{1}$$

The second step is direction change which is caused by paper component such as coating and filler. There are three phase function can be used to reflect photon direction change. They are Mie function, Henyey-Greenstein function and exponential cosine function [17]. Among them, Henyey-Greenstein function has been widely used with Monte Carlo method because its calculation advantage. It only needs two parameters, deflection angle β and anisotropic coefficient g shown by formula (2).

$$p(\cos\beta, g) = \frac{1 - g^2}{2(1 + g^2 - 2g\cos\beta)^{3/2}} \tag{2}$$

Recording the variation of photon is the final step. This step is the vital procedure deciding the accuracy of each output value because all the optical data are calculated based on photons energy. In the simulation process, energy variation mainly refers to photon energy attenuation. Supposing the original photon energy is w. After each stepsize move, energy could be record as w' and their relationship follows formula (3).

$$w' = \frac{\sigma_s}{\sigma_a + \sigma_s} w \tag{3}$$