Modeling ink diffusion within paper to achieve a raggedness ruler for print quality control

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Abstract

Raggedness is one of the most important print quality factors. It is defined as the appearance of geometric distortion of an edge from its ideal position that should be absolutely straight along the length of the line. Raggedness is caused by several phenomena. The non-uniformity absorption of ink, which may be because of the paper roughness or ink quality, may cause various degree of raggedness. Print quality assessments are usually based on comparing a test sample with a reference as a ruler of different quality samples. Therefore, it is important to prepare appropriate rulers for different quality metrics. The present study introduces a new method for modeling of raggedness by simulating ink diffusion within paper. It is assumed that different parts of a paper have different diffusion coefficients, so the ink can randomly diffuse through different paths. These paths can be changed via paper properties and drying time. Using this method and controlling the effective variables it is expected to generate different levels of raggedness. The experimental results show that with the proposed method it is possible to achieve different levels of raggedness, which can be used to generate test targets and raggedness rulers. Also, it can standardize objective and subjective test methods for measuring raggedness.

Introduction

Digital printing has been growing. Today, printers are employed in a variety of applications. As technology advances, need to be considered to achieve higher quality and much research is being done. In this context, a major challenge is how to measure the quality of the print. Quality control methods are divided into two general categories of subjective and objective. Due to the slow speed, low accuracy and cost of subjective ways, always trying to replace them with instrumental methods is considered.

Raggedness is one of the most important print quality factors. It is defined as the appearance of geometric distortion of an edge from its ideal position that should be absolutely straight along the length of the line [1]. Raggedness is caused by several phenomena. The non-uniformity absorption of ink, which may be because of the paper roughness or ink quality, may cause various degree of raggedness. Print quality assessments are usually based on comparing a test sample with a reference as a ruler of different quality samples. Therefore, it is important to prepare appropriate rulers for different quality metrics.

The present study introduces a new method for modeling of raggedness by simulating ink diffusion within paper.

Method

In this paper, it was tried to generate samples with different degrees of raggedness by simulating ink diffusion within a paper. It is assumed that different parts of a paper may have different diffusion coefficients, so the ink can randomly diffuse through different paths. These paths can be changed via paper properties and drying time. Using this method and controlling the effective variables it is expected to generate different levels of raggedness.

To be more familiar with the proposed method a brief description of Raggedness and Diffusion are given bellow.

Raggedness

Raggedness is the appearance of geometric distortion of an edge from its ideal position ideally edge should be absolutely straight along the length of the line. (Figure 1)

The main cause of raggedness is roughness of a paper that cause different diffusion factors in a paper. (Figure 2)

Figure 1. Raggedness

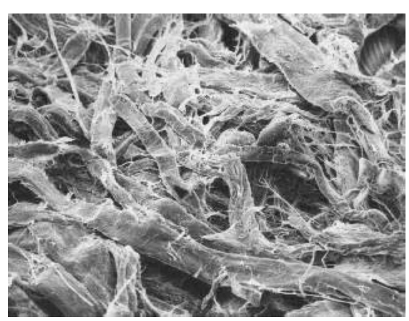

Figure 2. Microscopic image of a paper roughness

Diffusion

Diffusion is one of several transport phenomena that occur in nature. A distinguishing feature of diffusion is that it results in mixing or mass transport, without requiring bulk motion. Thus, diffusion should not be confused with convection, or advection, which are other transport mechanisms that utilize bulk motion to move particles from one place to another.

There are two ways to introduce the notion of diffusion: either a phenomenological approach starting with Fick's laws of diffusion and their mathematical consequences, or a physical and atomistic one, by considering the random walk of the diffusing particles [2].

In the phenomenological approach, according to Fick's laws, the diffusion flux is proportional to the negative gradient of concentrations. It goes from regions of higher concentration to regions of lower concentration. Sometime later, various generalizations of Fick's laws were developed in the frame of thermodynamics and non-equilibrium thermodynamics [3].

From the atomistic point of view, diffusion is considered as a result of the random walk of the diffusing particles. In molecular diffusion, the moving molecules are self-propelled by thermal energy. Random walk of small particles in suspension in a fluid was discovered in 1827 by Robert Brown. The theory of the Brownian motion and the atomistic backgrounds of diffusion were developed by Albert Einstein [4].

The concept of diffusion is widely used in: physics (particle diffusion), chemistry, biology, sociology, economics, and finance (diffusion of people, ideas and of price values). The concept of diffusion is typically applied to any subject matter involving random walks in ensembles of individuals.

Fick's law and equations

Fick's first law: the diffusion flux is proportional to the negative of the concentration gradient$J = -D\nabla n$, $J_i = -D\frac{\partial n}{n x_i}$ (1).

$$J = -D\nabla n,\ J_i = -D\frac{\partial n}{n x_i} \tag{1}$$

The corresponding diffusion equation (Fick's second law) showed in (2) and (3), where Δ is the Laplace operator.

$$\frac{\partial n(x,t)}{\partial t} = \nabla.\left(D\nabla n(x,t)\right) = D\Delta n(x,t) \tag{2}$$

$$\Delta n(x,t) = \sum_i \left(\frac{\partial^2 \mathrm{n(x,t)}}{\partial \mathrm{x}_i^2}\right) \tag{3}$$

Results & Discussion

A computer software was developed to model the ink diffusion in the paper. According to Fick's laws, the diffusion flux is proportional to the negative gradient of concentrations. In this software, the paper was assumed as a 2D matrix of different diffusion factors. Figure 3 show a schematic view of diffusion with different values of diffusion factor in each direction. A rectangle with custom concentration of ink was draw at the center of the matrix. The amount of initial ink concentration, the diffusion factor matrix of the paper, and time can determine the final raggedness image. The software was able to simulate the ink diffusion in steps of time. Because the generated diffusion factor matrix includes random diffusion factors, the flow of ink in the paper introduce raggedness defect in a synthesized image.

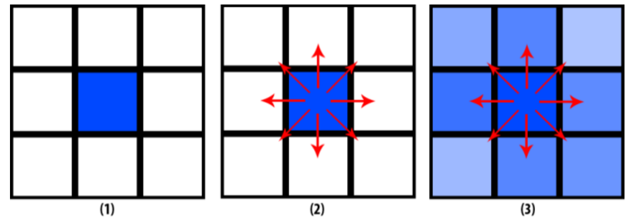

Figure 3. Schematic view of diffusion of ink in a paper

A set of raggedness images with different raggedness values generated with the proposed method are shown in **Figure 4**. The raggedness values of the synthesized images were computed by ISO/IEC DTS 24790 method. The results showed in Figure 4. As illustrated, it was possible to generated different degrees of raggedness as a kind of quality control ruler by the proposed method.

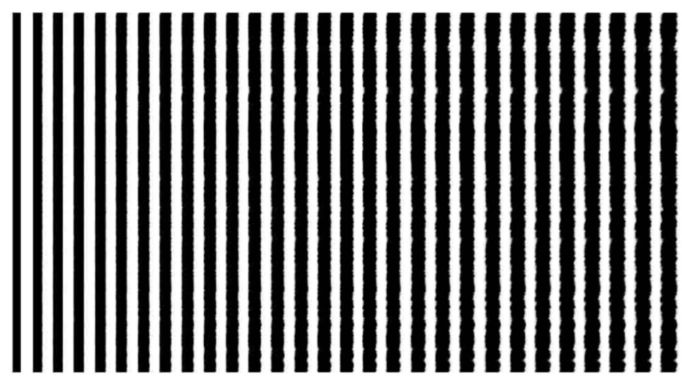

***Figure 4.** Generated raggedness images by the proposed ink diffusion method*

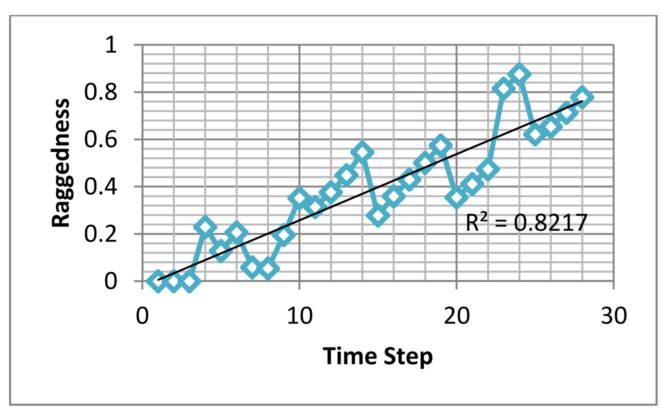

Figure 5. The ISO/IEC DTS 24790 raggedness values of the images of Figure 4.

Conclusion

This paper presents a new method for generating test targets for evaluating raggedness by modeling ink diffusion within a paper. The developed software is able to generate different levels of raggedness in each time step. These images can be used as test targets or raggedness ruler for visual assessment of raggedness for quality control in digital printing.

References

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Author Biography

Ali Azin is currently studying his MSc in Printing Science and Technology at Institute for Color Science and Technology with the Center for Image Processing in Printing technology. In BSc he worked on detecting painting defects using image processing. In particular he is interested in Color science, Painting and Printing inspections, Image Processing and Programming. Ali has an undergraduate degree in Color Science and Technology at AmirKabir University of Technology.

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