Lecture : 40

Enhancing Printer Imaging Systems

November 16, 2016

Abstract

This was a guest lecture given by Dr. Puneet Goyal on enhancing printer imaging system. In this talk, he focused on the methods to improve the quality of printing system. The talk was started with various available printing systems, their features and comparisons, the methods to improve it further, and the quality of the final system. The talk was concluded with the role of probability in the proposed improved printing system.

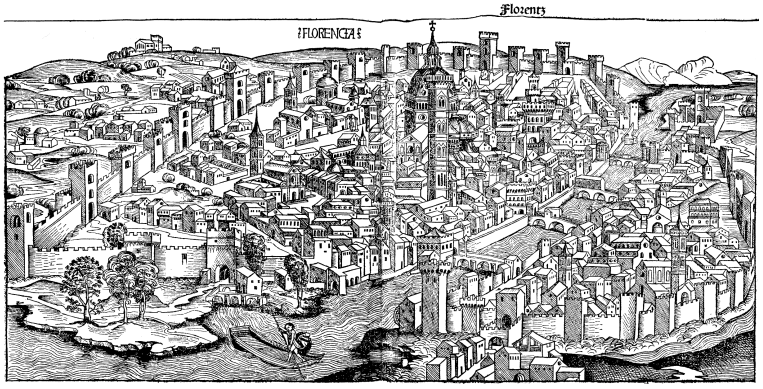
1 Introduction

In our daily life, we use so much printed materials. We start our day with a newspaper that is printed using these printing systems. We can't expect a day without the printing materials as everything we do is somehow is connected with printer, for example books, templates, menu cards, hard copy bills and so on. This shows the importance of the optimization of the printing systems. Even a small optimization in these systems will save a lot of time and resources. First we will discuss the preliminaries and then it will be followed by the proposed solutions.

2 Motivation and Background

The following topics will help you to be motivated for further discussion:

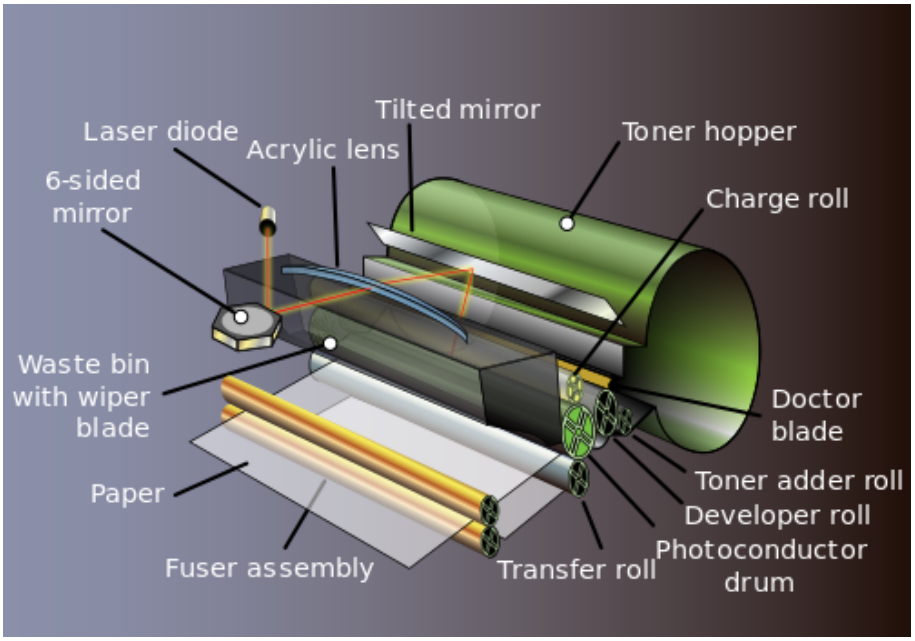
1. How does a printer work?
2. Revenue of Printing: It is $\$50B/yr$ for desktop printers and $\$300B/yr$ for commercial printers.
3. Importance of printing: We have discussed in the introduction but interested readers can explore further.
4. Gray Scale Printing: A grayscale image uses only black and white color, and the image is printed using the variations of gray tones between black and white. Following figure shows an example of grayscale printing.



5. Printer Mechnism: There are mainly two mechnisms are used: 1. Inkjet, and 2. Laser Electrographic.

6. Inkjet Printers: Inkjet printer prints by propelling droplets of ink onto the paper.

7. Laser EP Printers: It uses a laser beam to print the document on a selenium-coated drum using electrical charges. Following figure explains the model of a simple laser printer.



8. Comparison of Inkjet and Laser printers

9. Commercial Printer: These printers can print large amount of print faster. Few examples of commercial printers are given below:

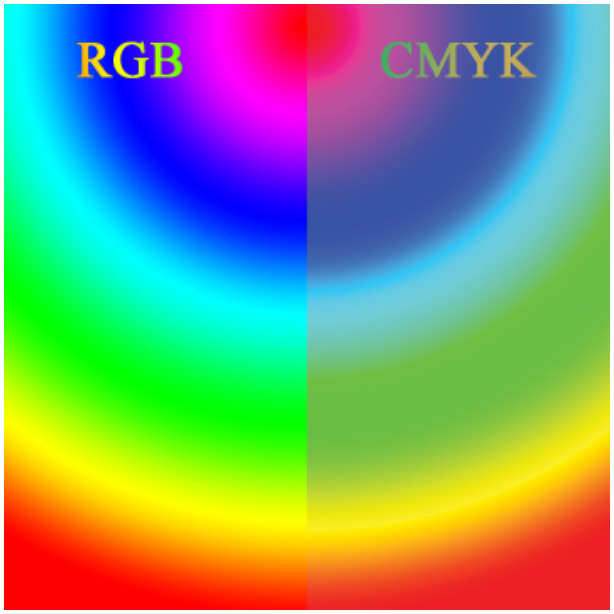
   - HP 1400 color inkjet
   - HP Scitex Inkjet Press

10. How to handle massive amount of data in printing?

11. The main objective functions to improve in printing systems: The printing systems should be faster, cheaper and should print high quality images. Except these due to market demand users also except more features in the printing systems. Most of the printers are connected through internet in big organizations, so printing systems should be able to process data that comes with the speed of internet.

12. CMYK Printer: This printer uses four colors cyan, magenta, yellow and key (black) to print an image. A sample cartridge of CMYK printer is shown below:

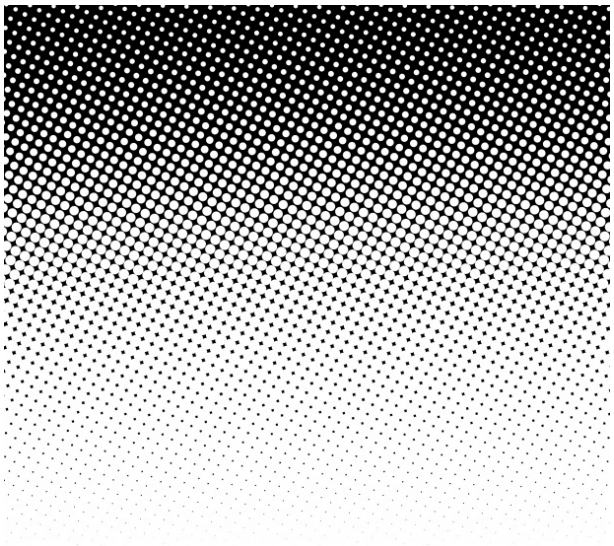
13. RGB Printer: These printers uses 3 colors to print an image. The following image shows the comparison of CMYK and RGB printer.



HP Indigo is the world leader in digital printing industry (75 percent world market shares for digital commercial photoprinting).

3 Preliminaries

1. Digital Halftoning: Digital Halftoning is a method to simulate different shades of gray by varying the size of tiny black dots arranged in a regular pattern. The following image shows a pattern halftone image.



2. Continuous Tone Image: In a continuous tone image, the color of each pixel of the image is reproduced as a single tone, not as the discrete halftones.

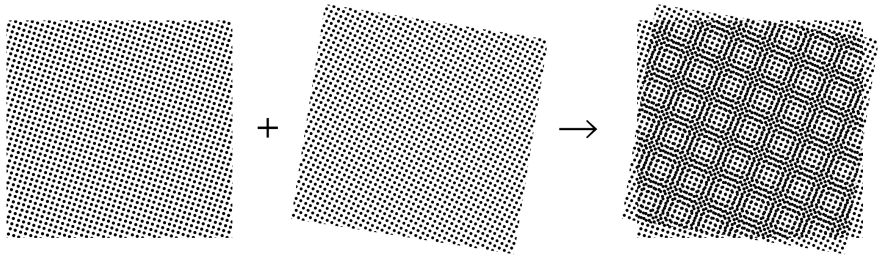
3. Half Tone Image: They are of mainly three types:

   (a) Aperiodic Dispersed Dot: They have following qualities: good detail rendition, stable.

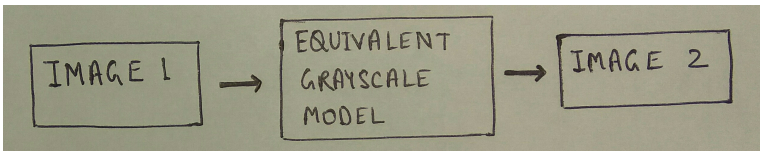
   (b) Periodic Clustered Dot: They have following qualities: smooth, stable, and visible periodic moire.

   (c) Aperiodic Clustered Dot: They have following qualities: stable and no periodic moire. These are also called stochastic image.

4. Moire Artifact: The following image shows moire effect. Interested reader can explore it further and its impact in the printing system.



5. Human Visual System: Human visual system is used to understand the capabilities of human eyes so that it can help to improve printing system.
6. Digital Halftoning: These have been used since ages for example: the same fundamental concept has been used in weaving and painting.
7. Halftoning Algorithms: The main halftoning algorithms are:
   - Screening Approaches
   - Neighboring Approches
   - Iterative Approaches
8. Error Diffusion Architecture
9. Conventional DBS(direct binary search) Cost Metric
10. Error Image: It is computed as: $e(m) = g(m) - f(m)$, where $g(m)$ represents halftone image(1 for black and 0 for white) and $f(m)$ represents continuous tone gray scale image. So the local optimal minima is found using itertaive approach, if the iterative model is used.
11. GrayScale Model: This model generates equivalent gray scale image. Fig. is shown below.



4 Prior Work

There are various types of printing model are available. We are going to discuss them next:

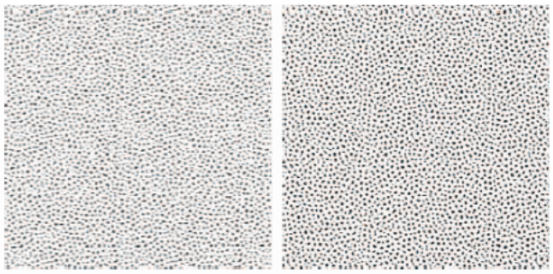
1. Physics Based Model
2. HCD(Hard Circular) Model
3. Scan Based EP Model: These can be further categorized in two categories:
   (a) Based on 3×3 neighborhood only
   (b) Based on 5×5 neighborhood only

5 The Proposed Methods

In this section, we will discuss the work done to improve the printing systems. The following methods have been proposed by Dr. Puneet Goyal. We will explain them in brief.

1. Electro-photographic model based stochastic clustered-dot halftoning with direct binary search: In electrophotographic printers, periodic, clustered-dot screening is used for rendering smooth and stable prints. But this does not work for the color printing due to the periodic moire between the halftones of color planes. In this work, authors propose a method that considers dot-gain and dot-loss effects. The stochastic model is used for the analysis of the same.

   The following image is taken from paper [4]:

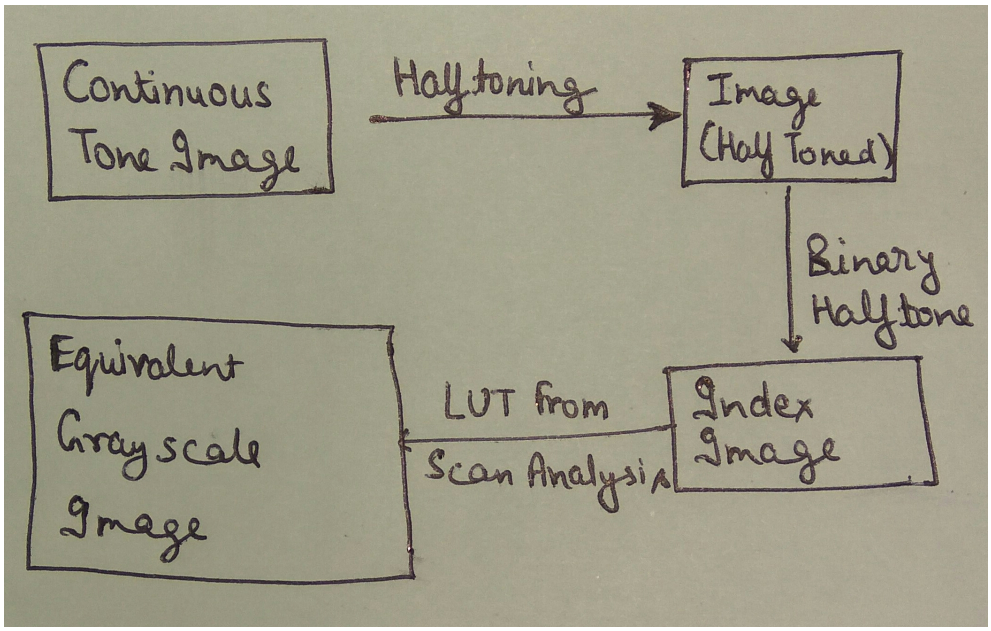


(a) CLU-DBS with no printer model (b) EPMB-CLU-DBS with printer model

Comparison of single level design halftones printed at 813 dpi (Mean equivalent grayscale value $\hat{g}_k = 0.27$

2. Stochastic clustered-dot screen design for improved smoothness: In this work, authors propose a method to study stochastic, clustered-dot screen design using Direct Binary Search (DBS). The proposed method uses modified cost metric that uses different filters in the initialization and update phases of DBS. The proposed method outperforms other existing methods and its implementation story was discussed in the class.
3. Cost function analysis for stochastic clustered-dot halftoning based on direct binary search: In this work, authors study a cost metric for CLU-DBS. This work further explains a method to avoid the inversion that is responsible for clustering.
4. Electro-photographic-model-based halftoning: In this work, authors study a stochastic model for dot interactions of an electro-photographic printer using the iterative DBS binary halftoning algorithm. The proposed method uses 5×5 neighborhood pixels to improve the printing quality. It reduces relative error from 21 percent to 4 percent.
5. Clustered-Dot Halftoning With Direct Binary Search: In this work, authors propose a method for aperiodic clustered-dot halftoning using direct binary search (DBS).

The next Fig. explains the halftoning analysis model that was discussed in the class.



Interested readers can explore bibliography for more details.

6 The Role of Probability in the Proposed Solutions

As we discussed in the class, the probabilistic model and least square regression were very handy to propose an improved solution for printing systems. Least square regression decreases number of printed pages for the analysis. We further discussed the importance of covariance in the error term, and its derivation is left due to the time constraint.

7 Bibliogrphy

The following works can be explored for more details:

1. Shacham, Omri, et al. "Method and system for enhancing a digital halftone representation for printing." U.S. Patent No. 8,537,423. 17 Sep. 2013.

2. Shacham, Omri, et al. "Clustered halftone generation." U.S. Patent No. 8,576,448. 5 Nov. 2013.

3. Goyal, Puneet, et al. "Clustered-dot halftoning with direct binary search." IEEE Transactions on Image Processing 22.2 (2013): 473-487.

4. Goyal, Puneet, et al. "Electro-photographic model based stochastic clustered-dot halftoning with direct binary search." 2011 18th IEEE International Conference on Image Processing. IEEE, 2011.

5. Gupta, Madhur, et al. "Stochastic clustered-dot screen design for improved smoothness." ISnT/SPIE Electronic Imaging. International Society for Optics and Photonics, 2011.

6. Goyal, Puneet, et al. "Cost function analysis for stochastic clustered-dot halftoning based on direct binary search." ISnT/SPIE Electronic Imaging. International Society for Optics and Photonics, 2011.

7. Goyal, Puneet, et al. "Electro-photographic-model-based halftoning." ISnT/SPIE Electronic Imaging. International Society for Optics and Photonics, 2010.