Method to Optimize Minimum Line Width and Edge Quality Without Sacrificing Maximum Area Fill Optical Density

Ana Cardells, Angel Martinez, Steve Steinfield and Jorge Castaño. Large Format Printing - Imaging and Printing Group Hewlett-Packard. Sant Cugat del Vallés, Spain.

Abstract

Minimum line width and black optical density (KOD) are key image quality attributes for AEC (Architectural Engineering and Construction) and MCAD (Mechanical Computer-Aided Drafting) markets. In the past, it has not been possible to simultaneously optimize line width and black area fill optical density with the same printmode. This has forced users that needed minimum line width to trade off optical density in black area fills, and vice versa. This trade-off is a well known product limitation for many inkjet printers. Further, throughput in these applications is improved by the use of bidirectional printing, however the directional differences in spot shape and placement cause degradation of line and edge quality. This invention gives a new method of processing image data that enables thinner, crisper lines, while maintaining maximum optical density in area fills, with the same fast bidirectional printmode.

Problem Statement

After several customer visits carried out by the Total Customer Experience (TCE) group together with Marketing, we have learnt that the most important attributes in AEC (Architectural Engineering and Construction) or MCAD (Mechanical Computer-Aided Drafting) markets are minimum black line width, area fill KOD (black optical density) and throughput. Unfortunately it has never been possible to optimize minimum line width and area fill KOD in one single printmode. To obtain acceptable area fill KOD, minimal black line width has always been traded off.

Traditional image processing pipelines do not allow using a different number of black ink drops in a 1/600 inch cell to print black lines or area fills. The number of drops is typically chosen to optimize KOD. This prevents lines to be as thin as they could be if fewer drops were fired.

In a traditional image processing pipeline for any object in a plot with a black level of 255 (pure black) the same mask (data containing information on the number and position of drops in a 1/600 inch cell) is used regardless if it is a line or an area fill.

Large format printing R&D experience tells that 3 dots are the optimal amount of ink per 1/600 inch cell to obtain good KOD, but then, line quality is significantly degraded. Also, the mask used to print lines does not take into account drop position and drop shape on paper to optimize line quality. On the other hand, to minimize line width and maximize line sharpness 2 drops are needed per 1/600 inch cell.

Our Solution

In order to maintain maximum KOD and optimal line quality we have introduced a modification into the traditional imaging pipeline (see diagram in figure 1). This modification consists of using two different masks when printing black lines or black area fills. A criterion exists to differenciate pure black lines from pure black area fills; a pixel is a part of an area fill if it is surrounded by at least two other pixels that have the same RGB value (i.e., are also black pixels) in all directions around it (above, below, right and left). If this condition is not true for a pixel it will be considered as part of a line.

The mask used when printing area fills can use as many ink drops as needed to maximize KOD. On the other hand, the mask used when printing lines can use a lower number of black ink drops and distribute them optimally to produce lines with minimum width and maximum sharpness.

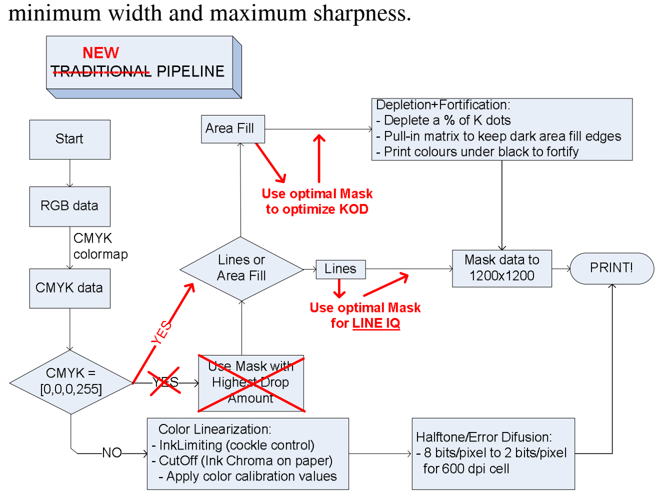

***Figure 1**. Modifications (in bold) performed to the traditional pipeline.*

The reason why specific masks optimize line quality is that they take into account that spots of ink on paper are not perfectly round, nor symmetrical, nor located consistently. This is caused by several factors:

1. Inkjet drops are not perfectly spherical, but consist of a primary drop and a secondary portion of the drop called "tail".

2.When printing bidirectionally, the aerodynamic effects on the tail relative to the primary drop cause the spot shape and main drop to tail distance to be a function of the direction and speed of the carriage movement.

Therefore, lines and edges that are printed in bidirectional printmodes consist of drops of different shapes and positional offsets. The magnitude of these shape and offset differences is well within the range of perception of the human eye, and results in a perceived imperfection in the quality of the line, such as line roughness (or line fuzziness).

Our solution allows using in a single printmode with two diferent specific masks one to optimize black line quality (minimum line width and sharpness) and the other to optimize area fill K. Moreover, our solution anticipates and compensates for the inherent asymmetry of the form of inkjet dots on paper. By means of this compensation, the perceived sharpness and thinness of printed lines are optimized without trading off area fill KOD.

Evidence the solution works

In order to prove that the solution works, some tests have been run to check the performance of different masks to optimize black line quality and black area fill KOD.

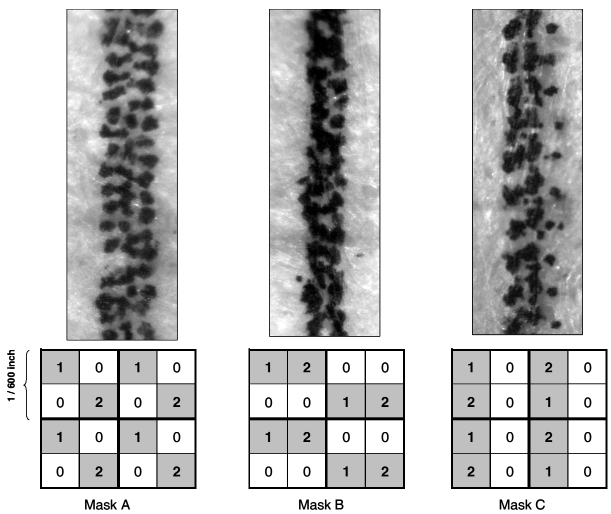

Figure 2. *Impact on line quality of dot position in a 2 pass printmode mask.*

To evaluate black line quality we have used a 50X microscope and an internal algorithm to measure both line width and roughness . In order to maximize line sharpness, masks should contain the optimal number and position of drops in a 1/600 inch cell. Figure 2 shows an example of three masks and the resulting lines (seen under 50X magnification). Masks are matrices where numbers represent the pass at which a dot is fired in a 1/1200 inch cell.

It is clear that the best line in terms of minimum line width and maximum line sharpness is provided by Mask B. This mask provides a disposition of dots on paper that forces tails to fall near the main drops. This increases the amount of ink in a given paper position and therefore increases line sharpness and minimizes line width. On the contrary, masks A and C make the tails to fall away from the main drops. This gives a higher ink drop dispersion on the paper and generates wider and fuzzier lines.

In the case of area fills, we have measured KOD with a colorimeter. From our tests we have found that in order to maximize KOD, masks should contain three drops in a 1/600 inch cell.

Conclusion from our tests is that our solution provides very thin lines and very dark area fills both in the same plot and using the same printmode. Trade-off between these two Image Quality attributes will no longer exist.

Competitive approaches, Current Status and Next Steps

To our knowledge no previous solutions exist to allow printing black area fills with the maximum possible KOD and at the same time having the minimum possible line width and maximum line sharpness.

One possible solution to optimize line quality is to use unidirectional printmodes (ink is fired in only one direction). However, unidirectional printing has approximately half the throughput of bidirectional printing, so the user would be forced to suffer a huge productivity hit in order to improve line and edge quality.

This invention has been developed and successfully tested for DesignJet T1100.

Author Biography

Ana Cardells holds an electronic engineer degree from the University of Barcelona (UAB, 2004). She has been working in the R&D lab in Large Format Printing in Hewlett-Packard for the last four years first in Writing Systems and then in the Color Team.