The optical interaction between ink and paper

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DIGITAL PRINTING CENTER

MID SWEDEN UNIVERSITY
Print quality of home & office ink jet
Scanner measurements

- Line: sharpness, raggedness, bleeding
- Print density
- Unevenness

- Colour gamut
  - A range of phenomena
  - What is caused by paper?
The optical interaction between ink and paper

Measurements and simulations (Kubelka-Munk & Murray-David)

- Optical properties of the paper
- Light scattering of the ink layer
- Ink penetration
- Non ideal light absorption of the inks
- Dot size
- Fluorescence
- Examples of different colour gamut
The light scattering ($s$) and light absorption ($k$) of paper and ink

Print density = $\text{Log}_{10}(R_{\text{paper}}/R_{\text{print}})$

**Paper:**
Low $k$ and high $s$ to achieve high reflectance

**Ink:**
High $k$ and low $s$ to achieve low reflectance
Plain paper, Coated paper and Photo paper
with fluorescence radiation of FWA
The light scattering of the ink layer from pores, pigment or surface roughness

<table>
<thead>
<tr>
<th>Slides</th>
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<tbody>
<tr>
<td>Photo gloss</td>
<td>2-3</td>
</tr>
<tr>
<td>Coated paper</td>
<td>2-2,5</td>
</tr>
<tr>
<td>Plain paper</td>
<td>1-1,5</td>
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</tbody>
</table>

Calculations using Kubelka Munk theory

Print Density

Ink weight g/m²
Simulation the effect of ink penetration
linear and with a barrier

Calculations using Kubelka Munk equations
Test printing; Print density vs. ink weight
The influence of ink penetration (hydrophobic sizing) and light scattering (filler)

Print Density

Ink g/m²

Water based ink jet

sized, no filler
not sized, no filler
sized, filler
not sized, filler
Ink jet print with ink amount 1 g/m² and 5 g/m²

1 g/m²

5 g/m²

The ink adsorbs to the fibres
Penetration of ink into plain paper
determination with Kubelka Munk theory

Spectrophotometer

\[
\ln \left( \frac{F(R_0, R_\infty) \times F(R_p, R_\infty)}{F(R_q, R_\infty)} \right) = \ln(F(R_0, R_\infty))
\]

\[
Pen\% = 100 \times \frac{F(R_0, R_\infty) \times F(R_p, R_\infty)}{F(R_q, R_\infty)}
\]
Ink jet print with sex different ink amount
Plain paper

Printed side

Back side
Penetration of ink into plain paper
Determination based on reflectance measurements

Ink penetration

%

0 20 40 60 80 100

Ink g/m²

0 2 4 6 8 10 12

Cyan
Magenta
Yellow
Blue
Red
Green

Blue=C+M
Red= Y+M
Green=C+Y
Plain paper and Photo gloss paper
The influence of ink penetration and light scattering

Plain paper:
Low Colour Gamut

Photo Gloss paper:
High Colour Gamut

Ink jet prints

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Test chart for measurement of Colour Gamut

RGB coordinates

Magenta  Cyan  Yellow

Upper

Lower

RGB coordinates:

- Magenta: RGB (255, 0, 0), CMY (0, 100, 100)
- Cyan: RGB (0, 255, 0), CMY (100, 0, 100)
- Yellow: RGB (255, 255, 255), CMY (0, 0, 0)

Test chart includes:
- Upper section for Magenta and Cyan
- Lower section for Cyan and Yellow

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Colour gamut of Photo gloss paper compared to plain paper

Photo gloss paper has a top layer of low light scattering
Calculation of the colour gamut

\[ k \text{ of process inks} \]

\[ s \text{ and } k \text{ of paper} \]
Calculated colour gamut

High ink penetration

Low ink penetration

Low light scattering
Process inks
increasing ink weights (Ink jet)

Transmittance  Absorption
Increasing ink weight
Calculation using Kubelka-Munk theory

Gamut area

L*

b*
a*
Colour area
Measurements with spectrophotometer

What is the best ink level for ink jet?

sized, no filler
not sized, no filler
sized, filler
not sized, filler
Comparison ideal inks and process inks
Calculations using Kubelka Munk theory
the upper part of colour gamut
The difference between offset and Ink jet
Measurements with spectrophotometer

Offset is smaller with a concave shape
Light absorption of process inks are similar

Ink jet

Offset

Offset: Prüfbau on Mylar film 0-4 g/m²
Inkjet: Ink jet on transparency 0-5,5 g/m²
Colour half toning

Ink jet photo gloss

Colour control:
Changing the dot size
Changing the dot frequency
Changing the ink amount

Offset

Colour control:
Changing the dot size
(Changing the dot frequency)
Dot gain or tone value increase

Mechanical and optical dot gain

‘Corona’
Comparison of large and small dots

Test printing with inkjet

Large (condensed) dots

Small (disperse) dots
Comparison of large and small dots

Test printing and measurements with spectrophotometer

Gamut

Tone value increase at 40%

Convex/Concave

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Halftone and continuous tone

Compared at ink amount per unit area

<table>
<thead>
<tr>
<th>Tone value %</th>
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<tbody>
<tr>
<td>0%</td>
</tr>
<tr>
<td>25%</td>
</tr>
<tr>
<td>50%</td>
</tr>
<tr>
<td>75%</td>
</tr>
<tr>
<td>100%</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Ink weight g/m²</th>
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</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>0,50</td>
</tr>
<tr>
<td>1,00</td>
</tr>
<tr>
<td>1,50</td>
</tr>
<tr>
<td>2,00</td>
</tr>
</tbody>
</table>

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Simulation

Half tone: Murray David 2, 3 and 4 g/m²
Continuous tone: Kubelka Munk 0-2, 0-3 and 0-4 gm²

Continuous tone is more effective than half tone
Simulations

Half tone: Murray David 2, 3 and 4 g/m²
Continuous tone: Kubelka Munk 0-2, 0-3 and 0-4 g/m²

Half tone is more linear than continuous tone in $a^*$ vs. $b^*$ plots
The tone values 0-100 %
measurements on prints with three ink levels

Offset & ink jet

large & small dots

Offset
Ink jet

large
condit L
disp L

small
condit M
disp M

large
condit H
disp H

small
condit L
disp L

large
condit M
disp M

small
condit H
disp H

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Simulation for increased ink level

for half tone and continuous tone

0.6 g/m²

0.9

1.2

Half tone has concave shape of gamut

continuous tone has convex shape
The difference between offset and Ink jet
Measurements with spectrophotometer

Offset is smaller with a concave shape

Offset

Ink jet
Two different printers
Plain paper

Printer 1

Printer 2

Grid with ICC profile

Grid with colour correction of the printer

The effect of Key black?
Measurements of Colour gamut
With spectrophotometer

Colour gamut

KDE

Un coated  Coated  Photo gloss

0  200  400  600  800

OfsUnc  XerUnc  I-JetUnc  OfsCoat  XerCoat  I-jetPh  I-jet2Ph

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Photo ink jet
with and without colour correction

Grid: No colour correction
Even ton steps

Grid: Colour corrected with ICC profile

Aggregation due to gamut mapping
Summary

• High reflectance of the paper and low light scattering of the ink layer is needed to get high gamut

• Ink penetration should be low (hydrophobic treatment, barrier, dye fixation)

• Non ideal properties of process inks explain the darkening and colour strength reduction for higher ink weight

• The small dot size of ink jet can explain the convex shape

• The fluorescence influence the shape of gamut and is a problem in colour management work

• The use of Key Black can explain the tornado shape

• Colour correction influence the evaluation of colour gamut
The RGB star

sRGB D50/2

Printer1 no colour correction

Printer1 with ICC profile

Photo quality
Half tone and continuous tone
process inks and ideal inks