Resolution or more colours - Making the choice

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First generation of desktop ink-jet printers:

- Limited spacial resolution and precision
- Big drop size
- Bi-level
- 3 or 4 inks
- Slow host-printer interface
- Draft quality

Actual state-of-the art desktop ink-jet printers:

- Medium and high resolution and precision
- Appropriate drop size
- Multi-level
- Multi-ink
- Fast host-printer interface
- Photo quality

High-Speed ink-jet printers

- Relatively low resolution and precision
- Multi-level
- Multi-ink
- Fast host-printer interface
- Very high speed (meters/sec)
- Multiple nozzle architecture

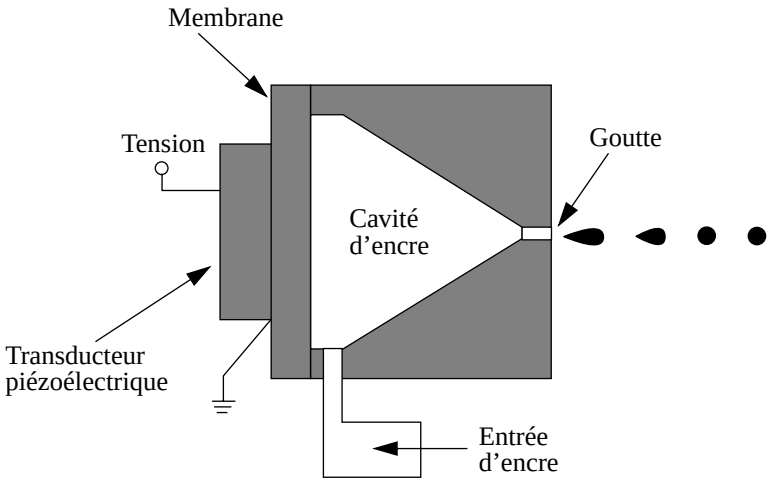
Technical Choices:

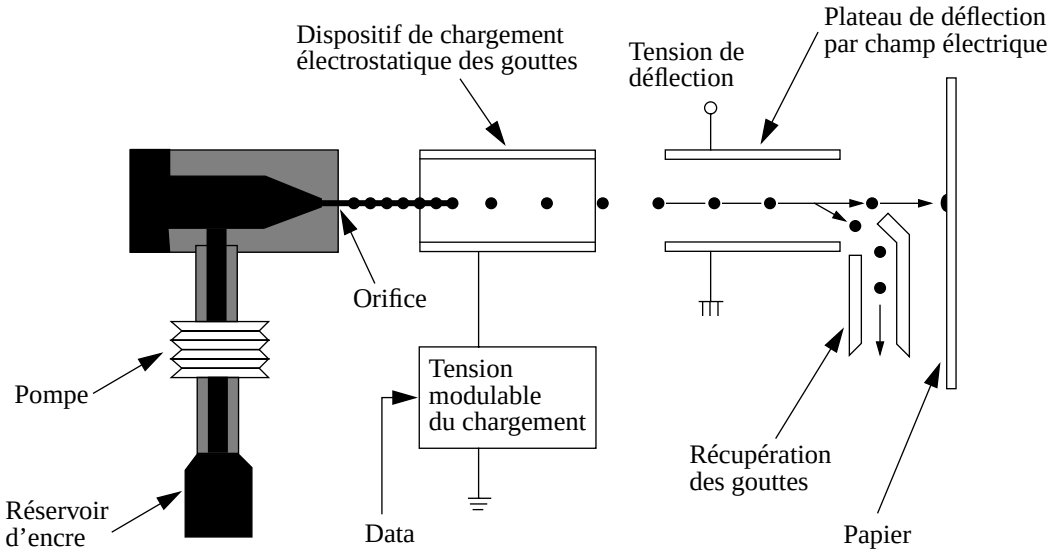
- Increase resolution/precision
- Diminish drop volume
- Increase number of levels
- Increase number of colours
- Parallel nozzle architecture

Criteria for choice:

- Visual quality (custermers' satisfaction)
- Cost
- Speed
- Availability of the technology (hardware/software)
- Competitors' offer

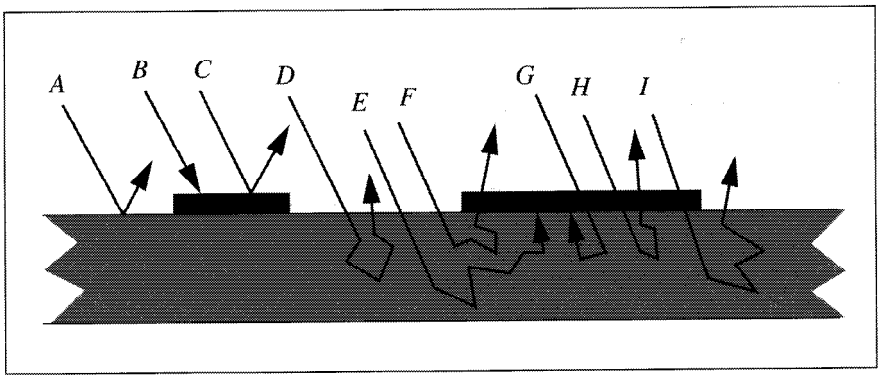
Basic hardware technology: drop-on-demand and continuous-jet printers



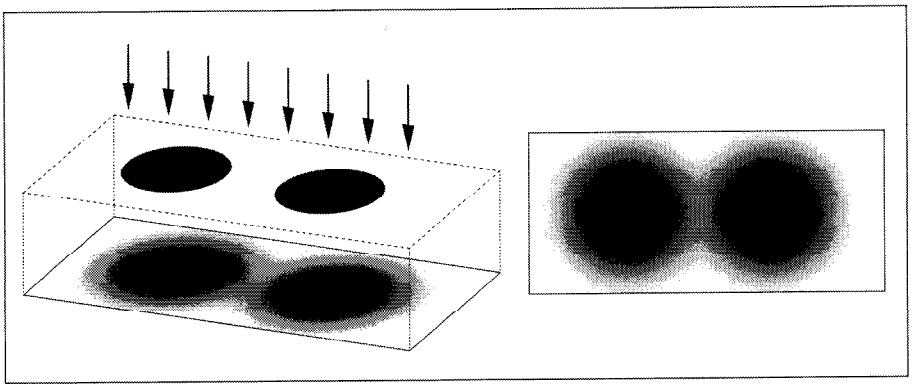


Physical and Optical Dot Gain

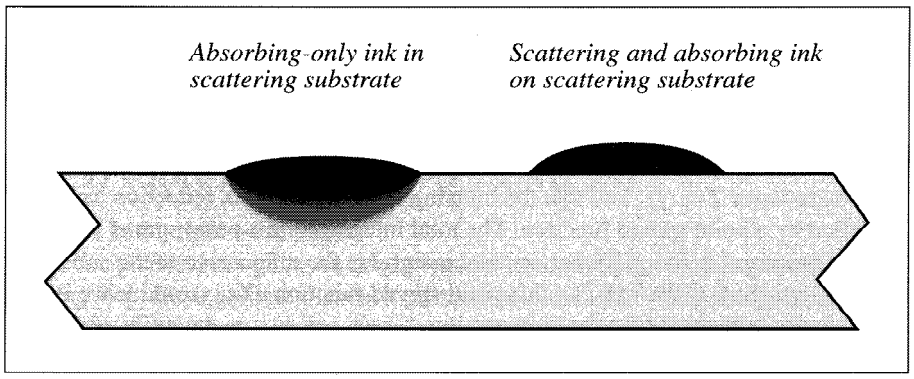
(Source: [Guistavson97])



Possible paths in a halftone print for an incident photon



Optical dot gain as a result of diffuse bulk reflection

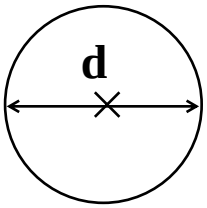


Penetrating ink (left) and a simplified model (right)

Modeling Dot Gain:

Simple drop model

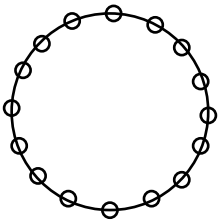
a) center



center: random position variation

↕ + 5%d; ↔ + 15%d

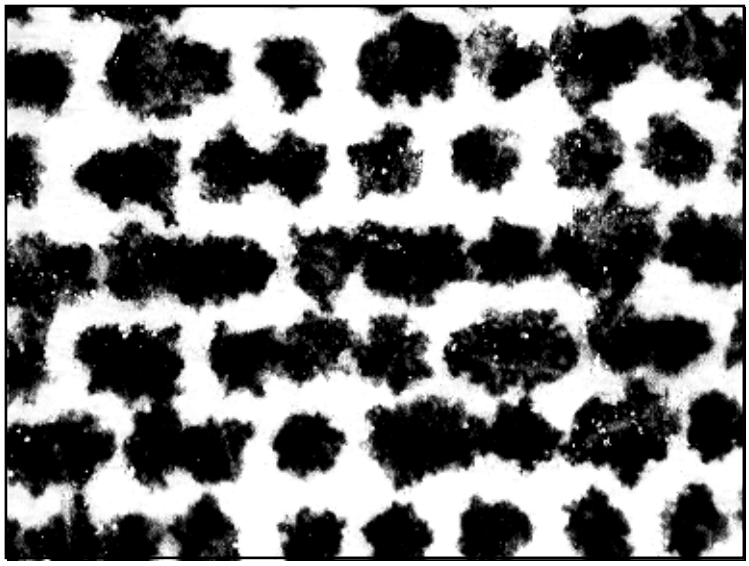
b) boundary

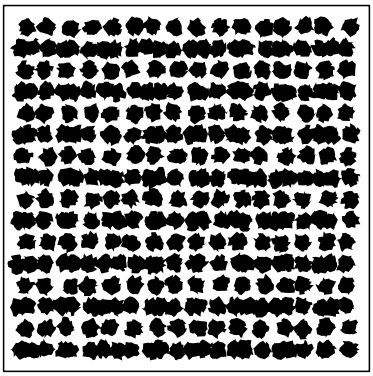


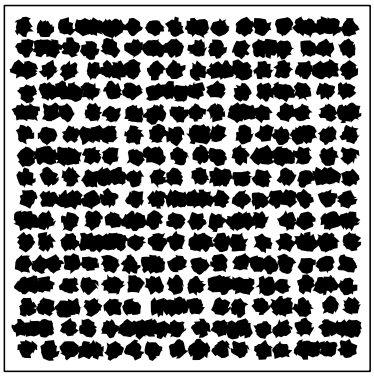
each point: random position variation

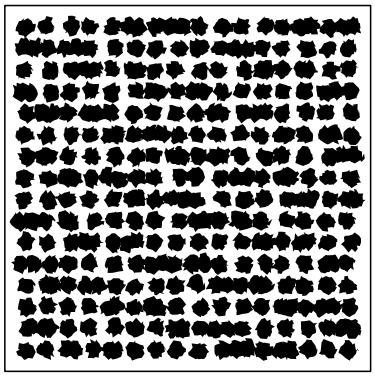
↕↔ + 10%d

Photomicrography



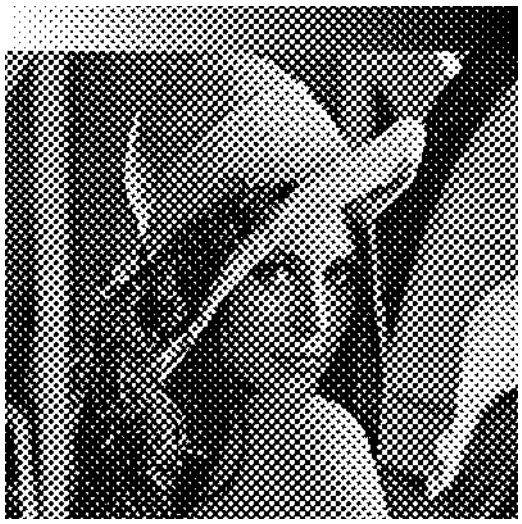


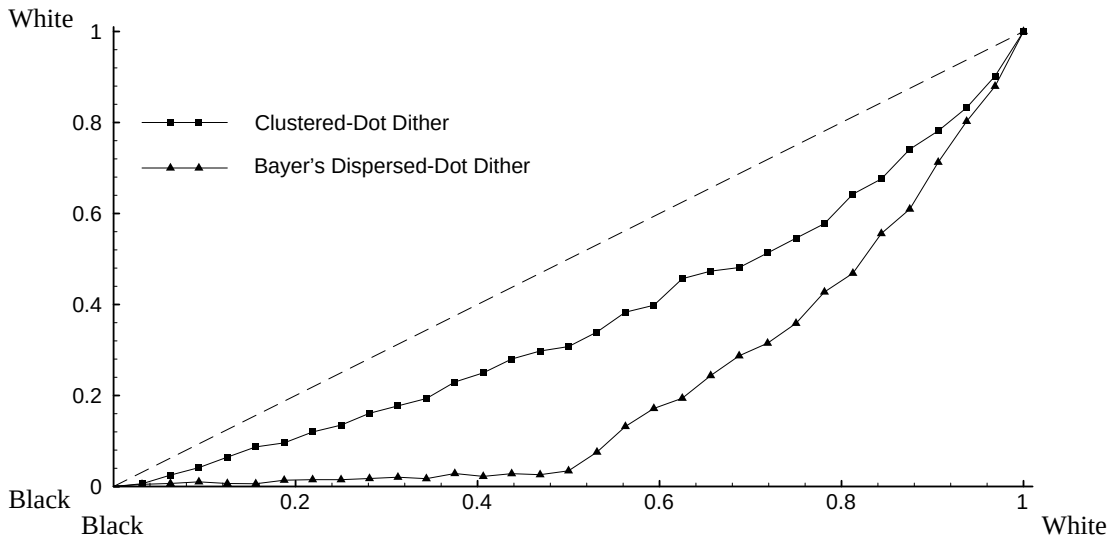




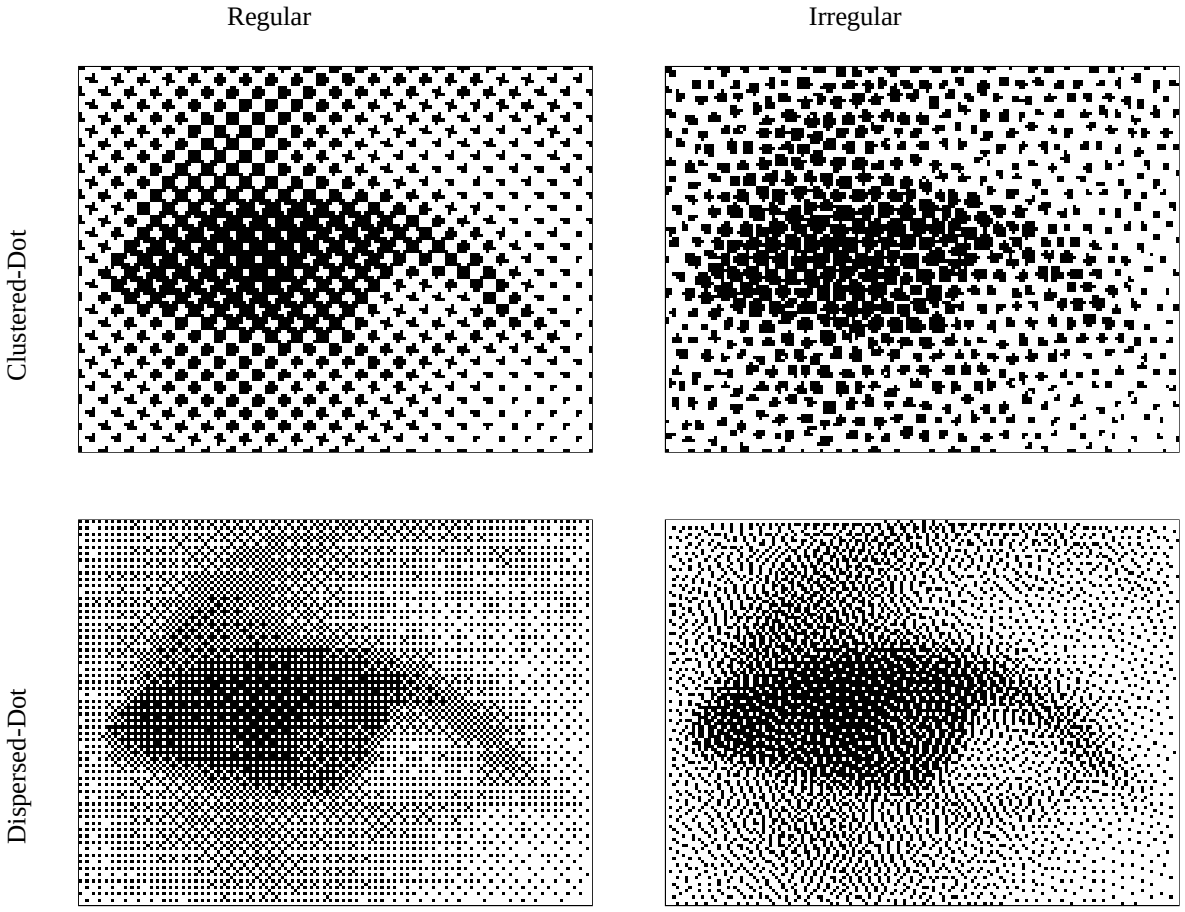
Simulated Samples

Tone Reproduction Curve

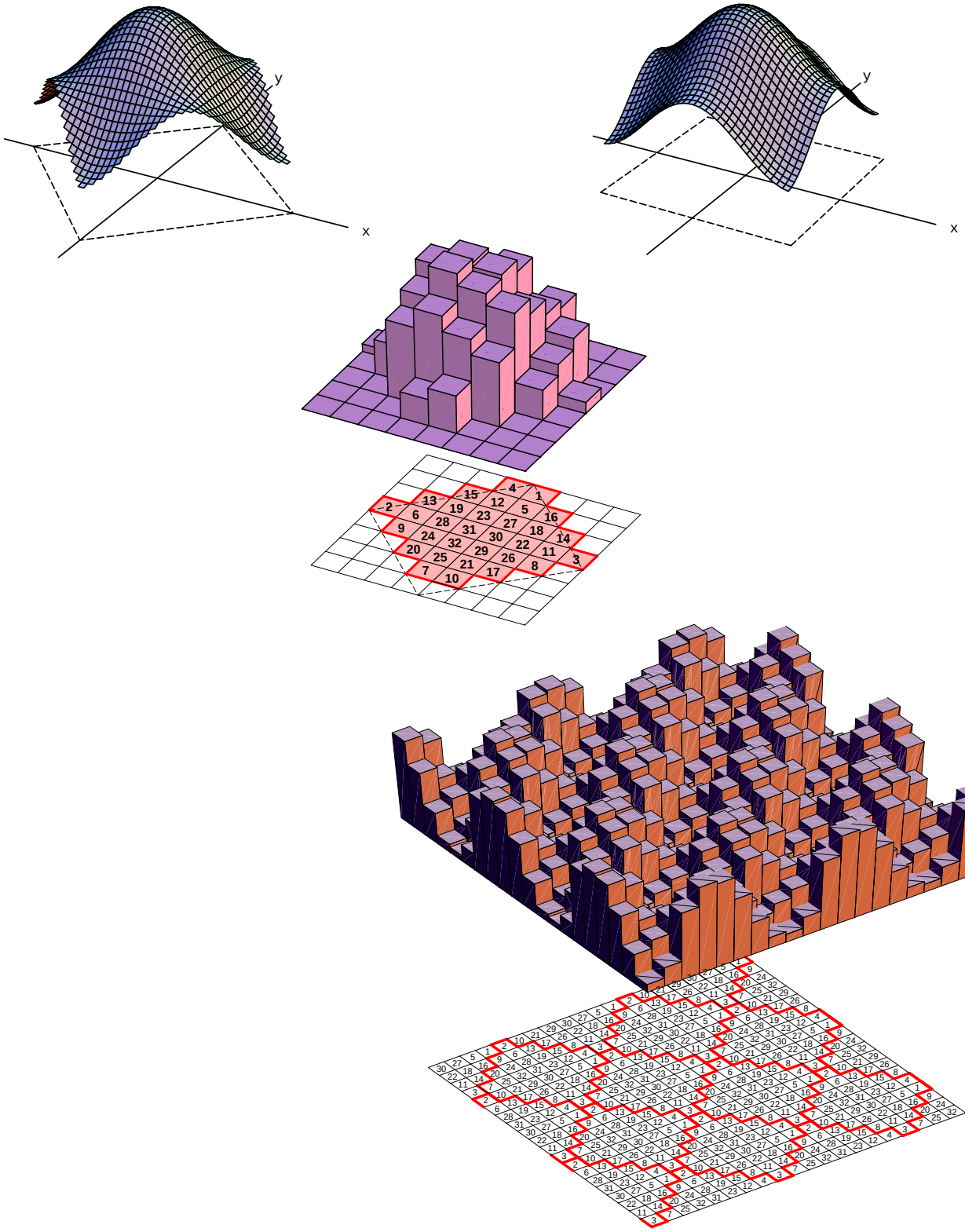




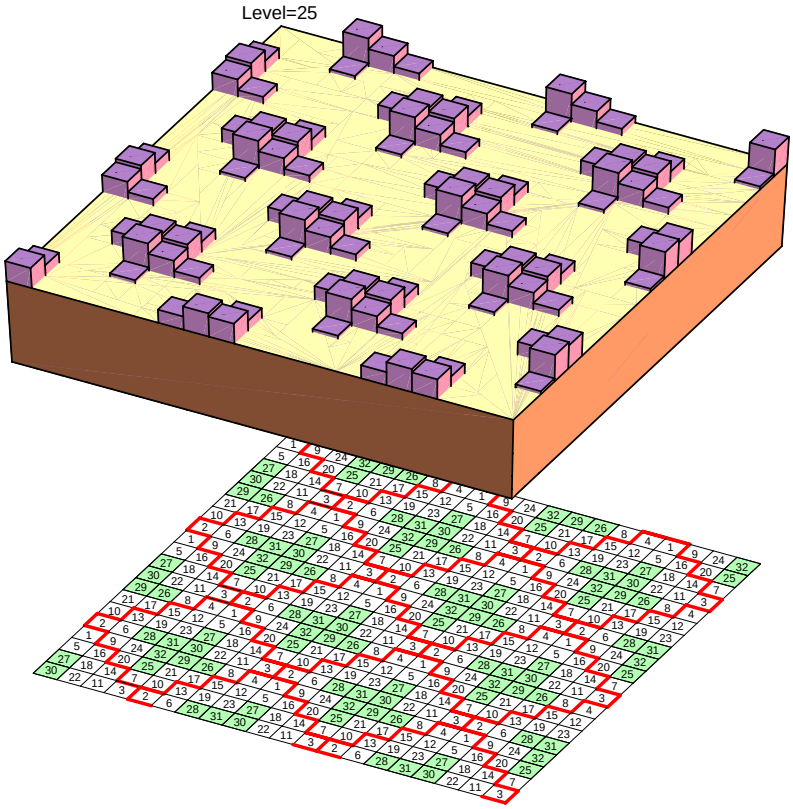
Basic halftoning techniques for ink-jet printers:



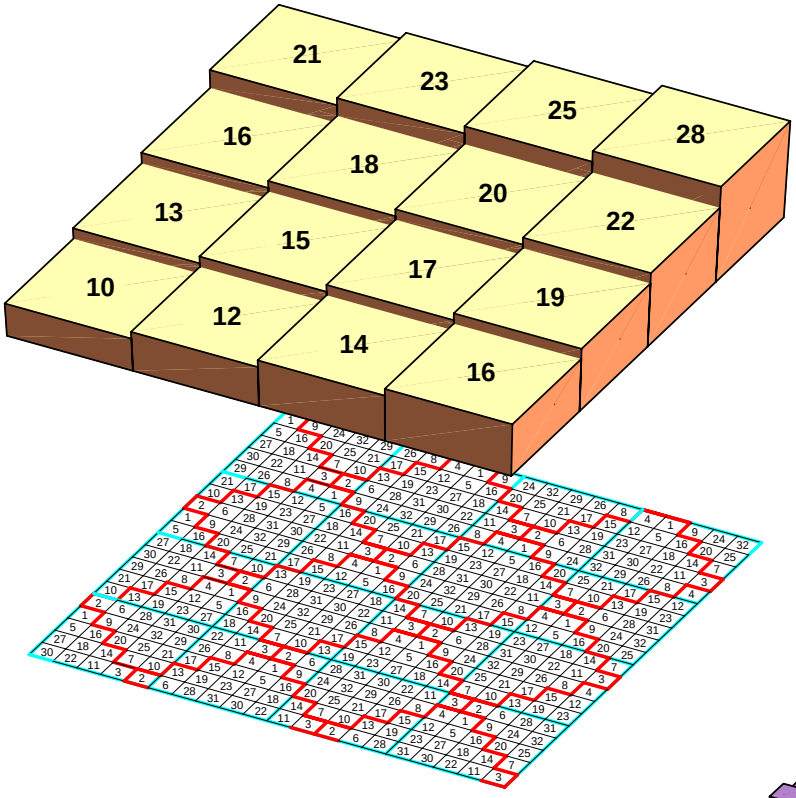
Building Spot Function

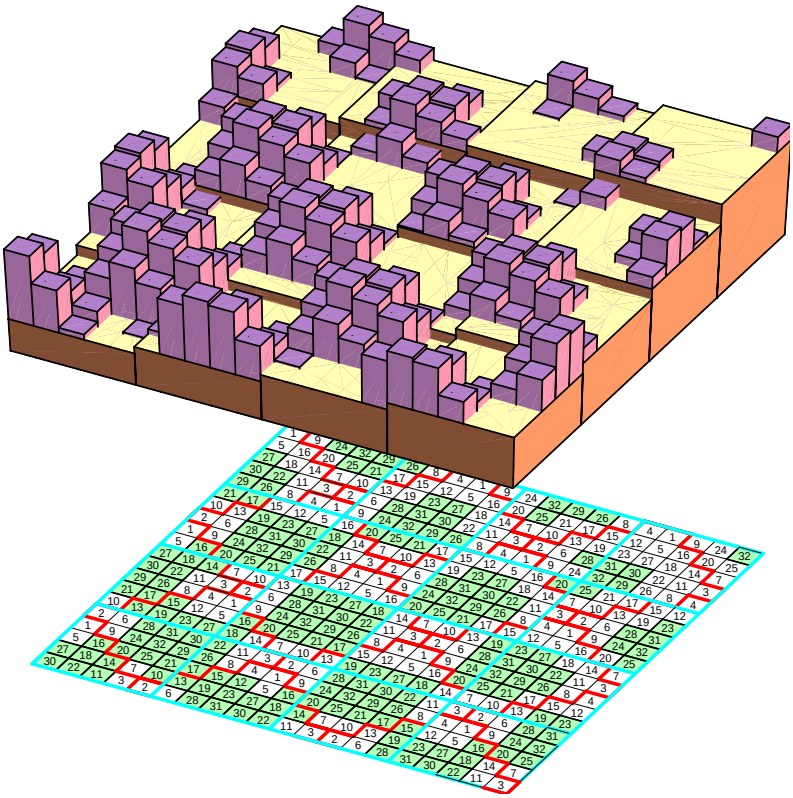


Applying Spot Function: Constant input level

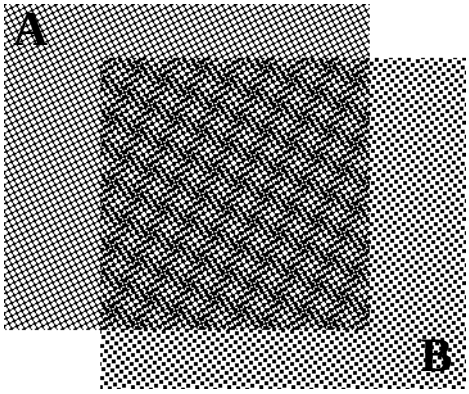


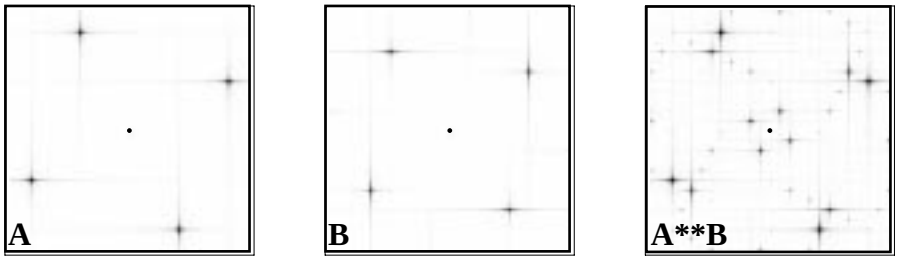
Applying Spot Function: Variable input level

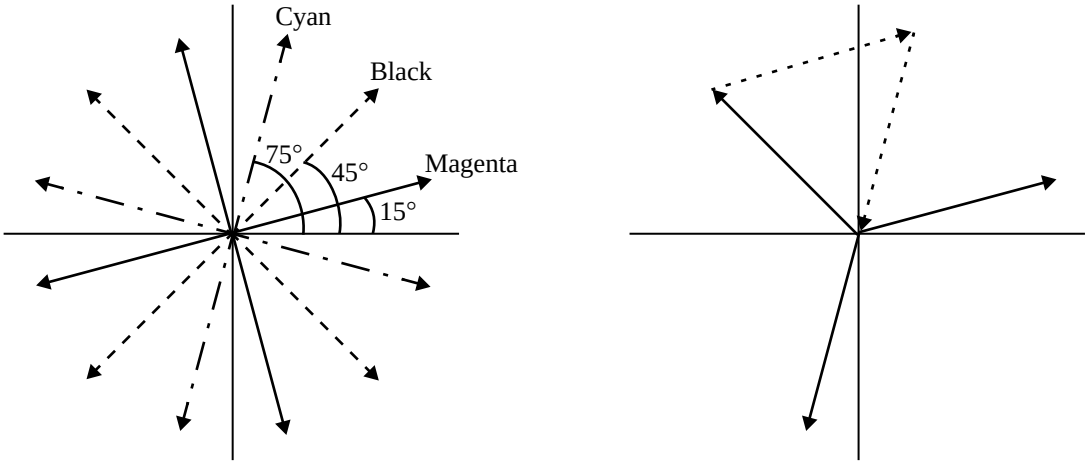




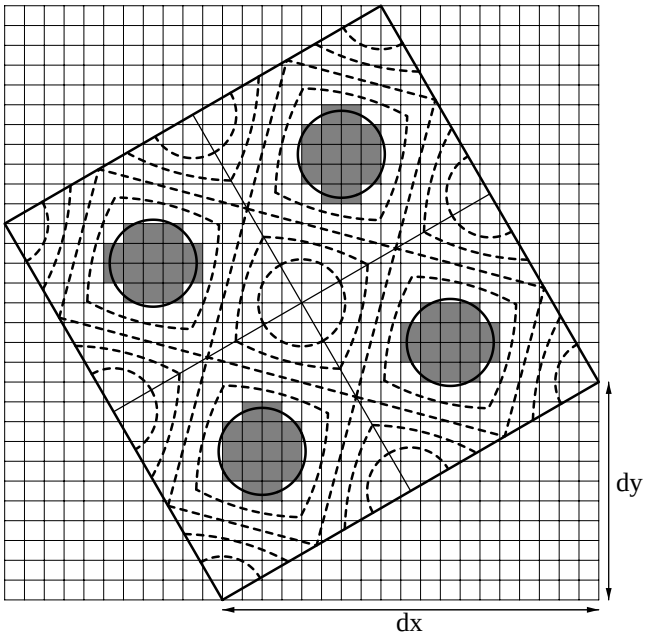
Moiré



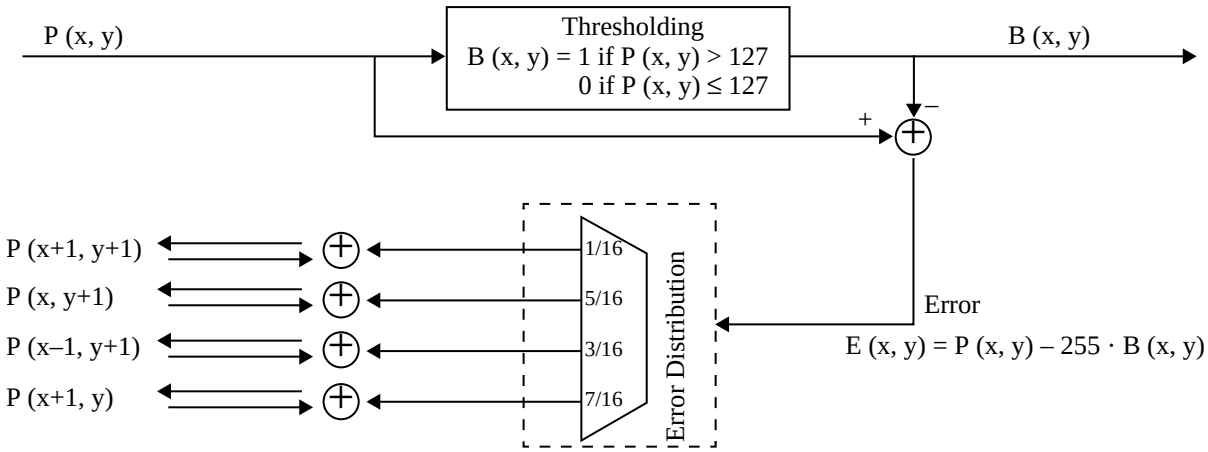




Super-cell



Error-Diffusion: Floyd-Steinberg



A Typical Result

Error-Diffusion: Different Distribution Schemes

$$\left(\frac{1}{16}\times\right)\quad \begin{matrix} & \bullet & 7 \\ 3 & 5 & 1 \end{matrix}$$

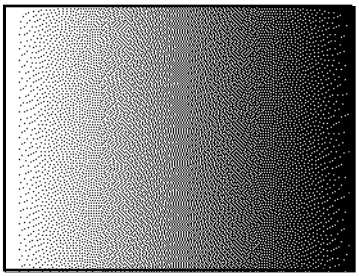
(a) Floyd and Steinberg

$$\left(\frac{1}{48}\times\right)\quad \begin{matrix} & & \bullet & 7 & 5 \\ 3 & 5 & 7 & 5 & 3 \\ 1 & 3 & 5 & 3 & 1 \end{matrix}$$

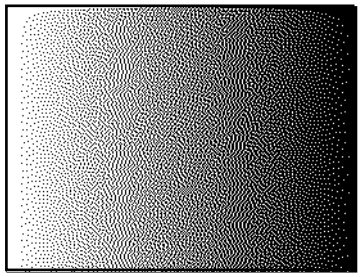
(b) Jarvis, Judice and Ninke

$$\left(\frac{1}{42}\times\right)\quad \begin{matrix} & & \bullet & 8 & 4 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \end{matrix}$$

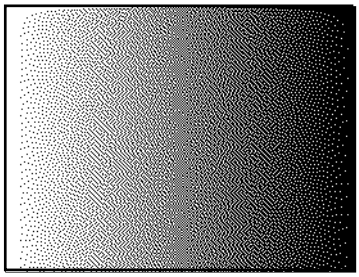
(c) Stucki



(a) Floyd and Steinberg

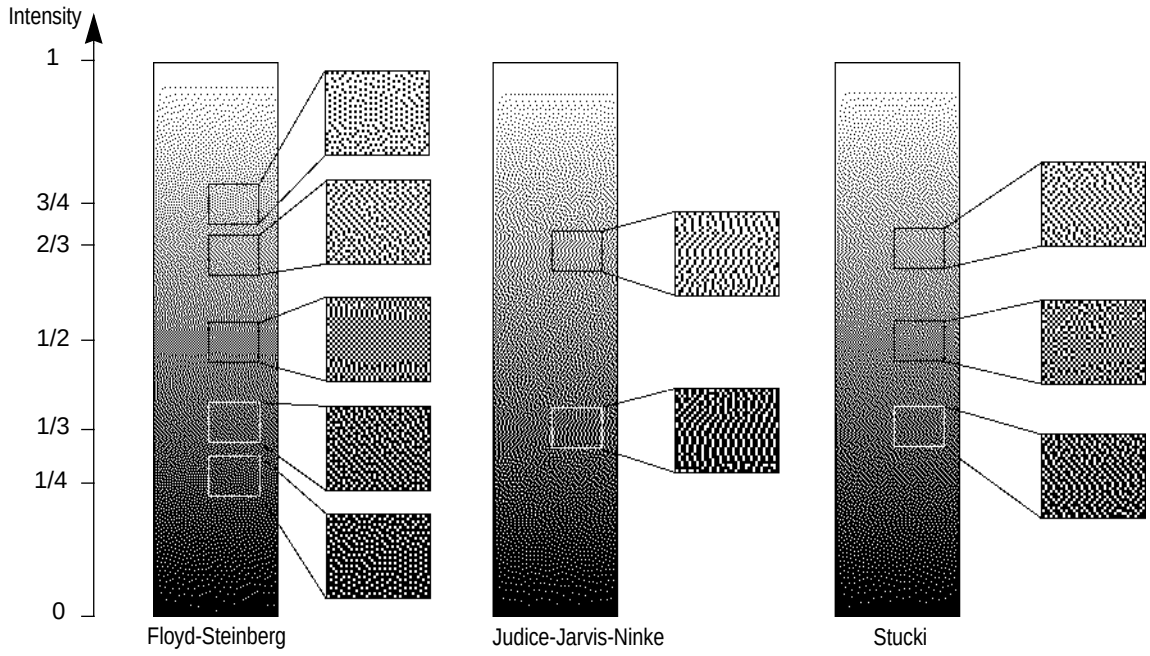


(b) Jarvis, Judice and Ninke

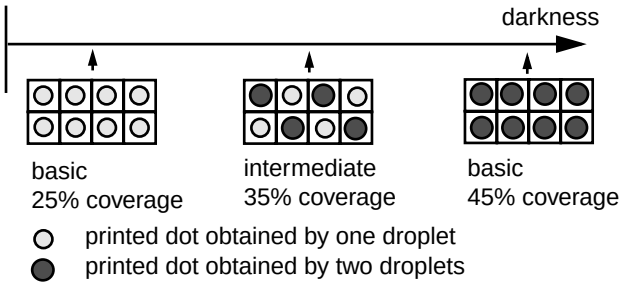


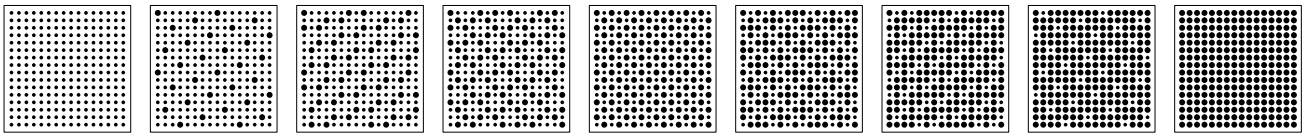
(c) Stucki

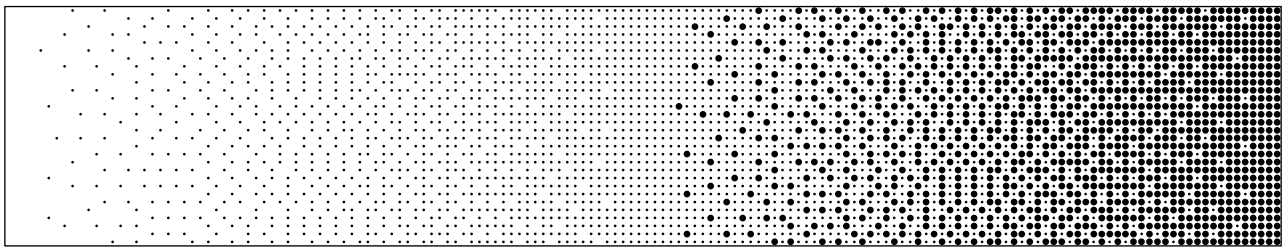
Error-Diffusion: Major Artifacts



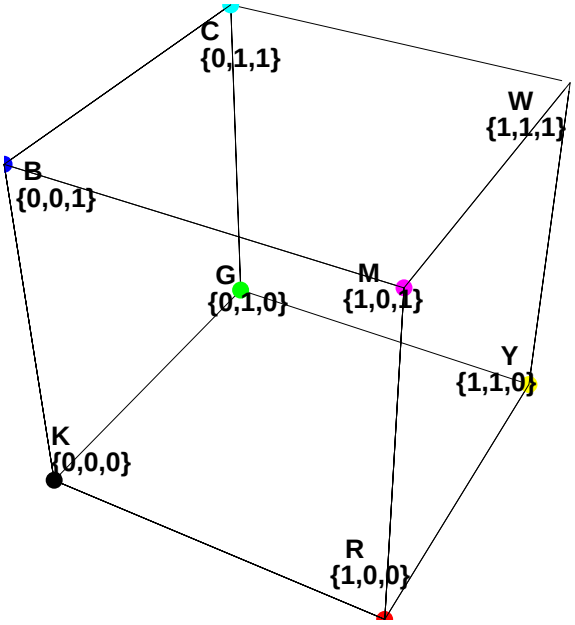
Multi-Level Halftoning

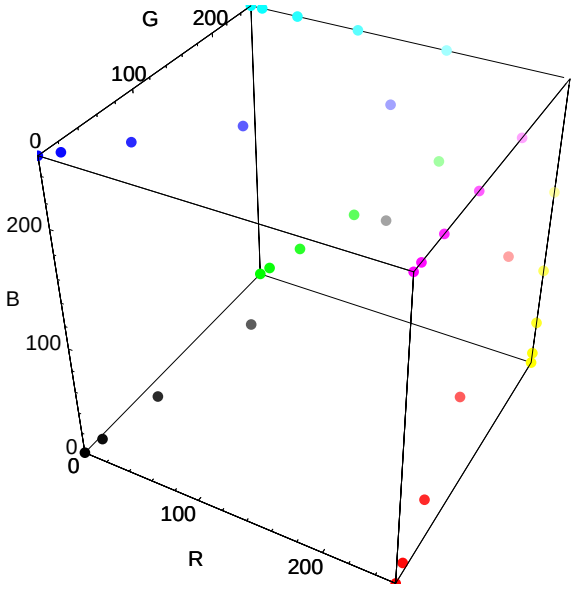


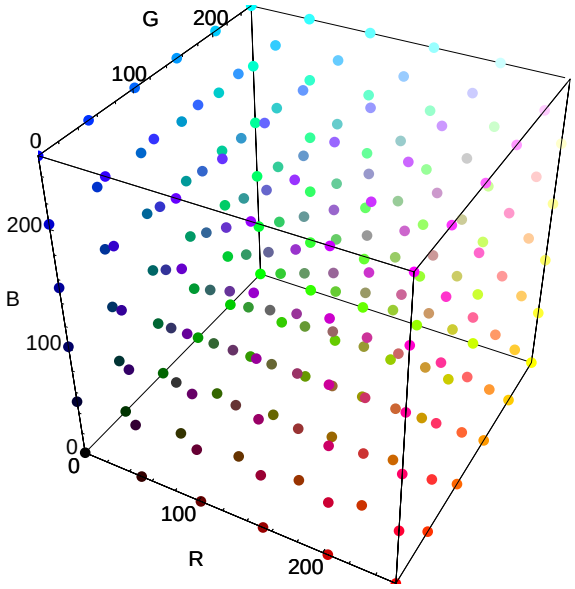


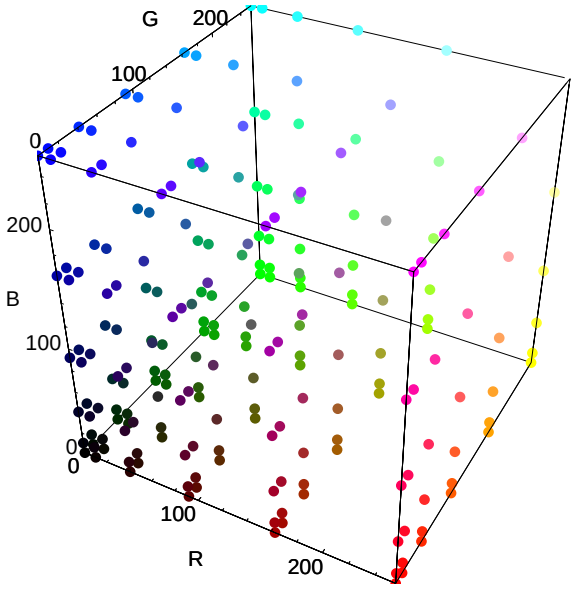


Colour Palettes for Multi-Colour Printing

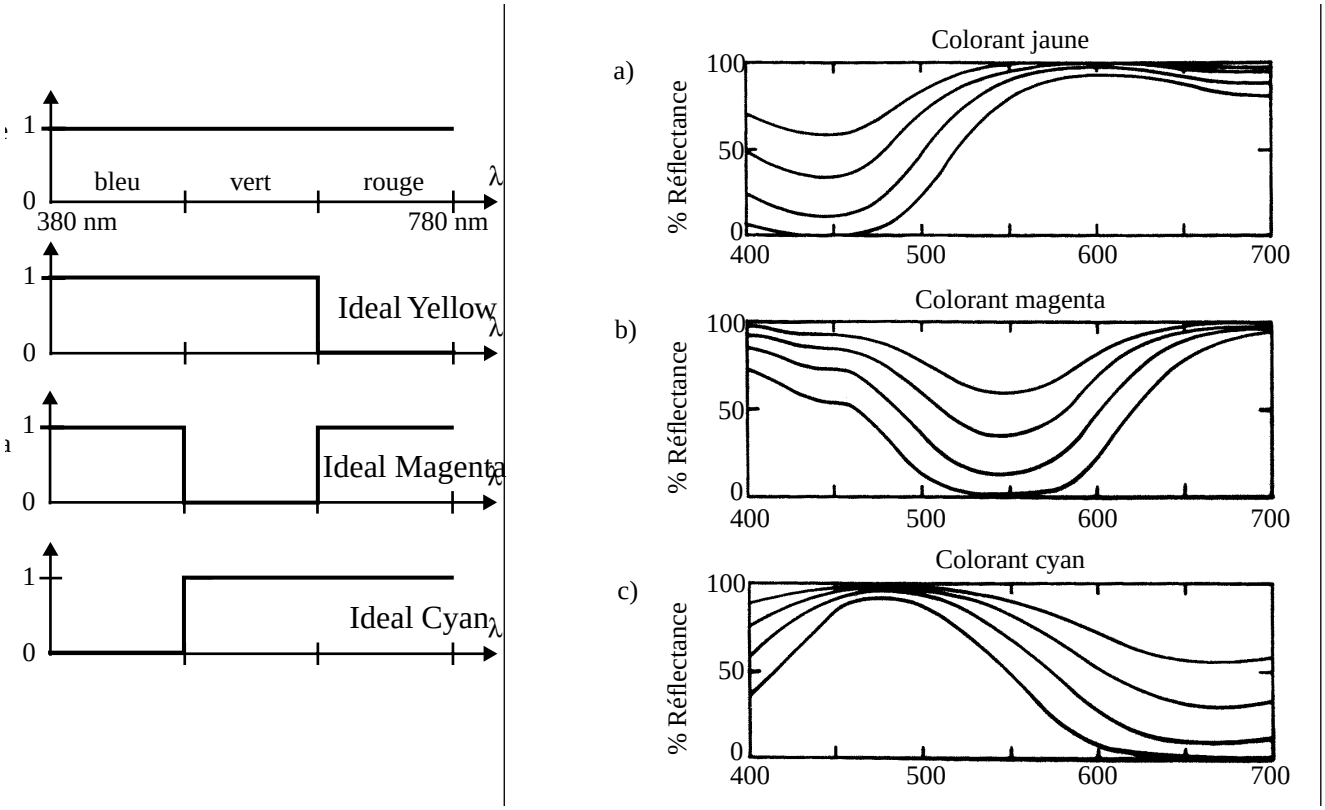


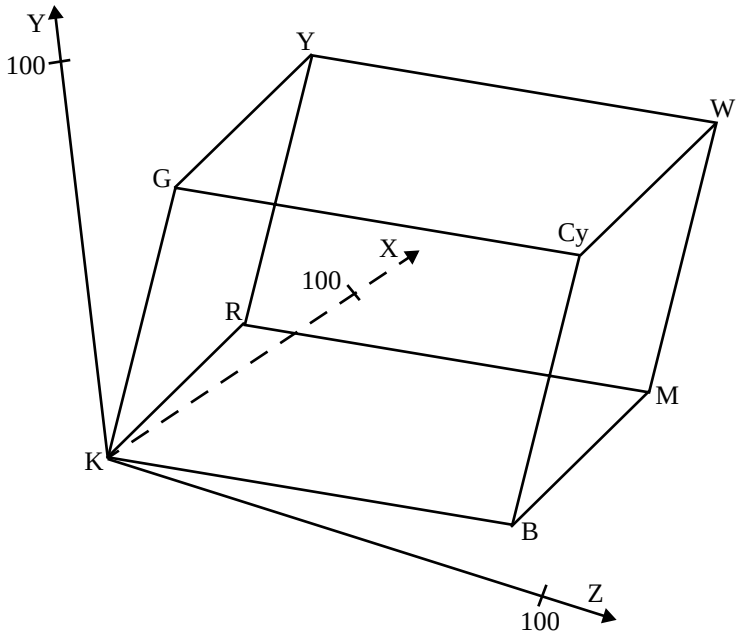






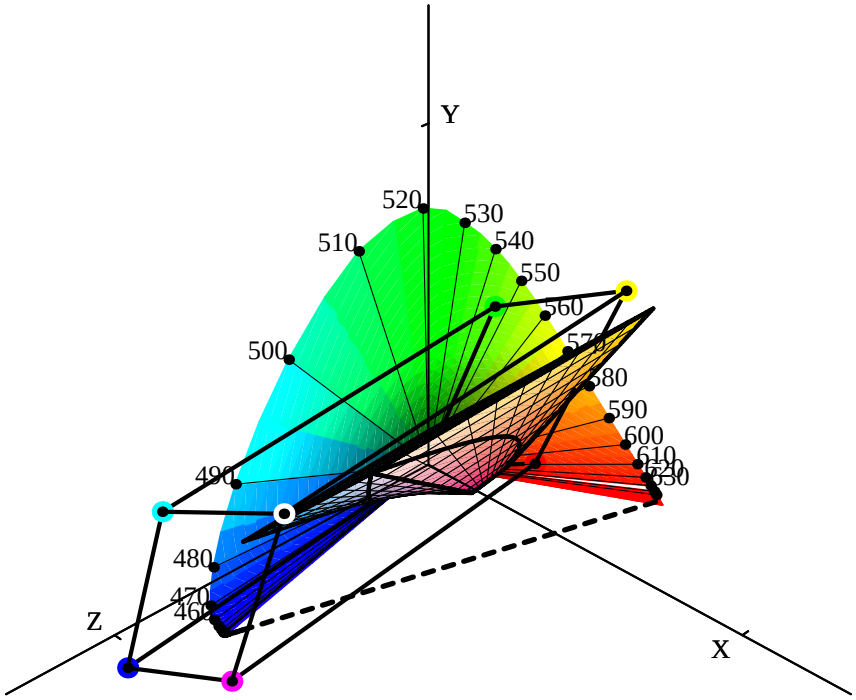
Ideal vs. Real Dyes

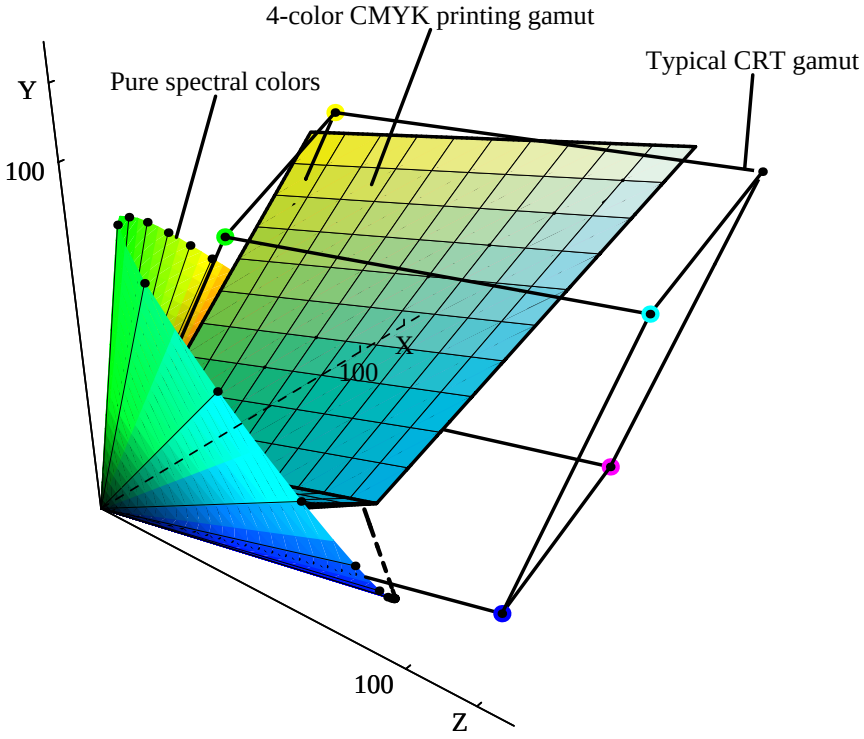




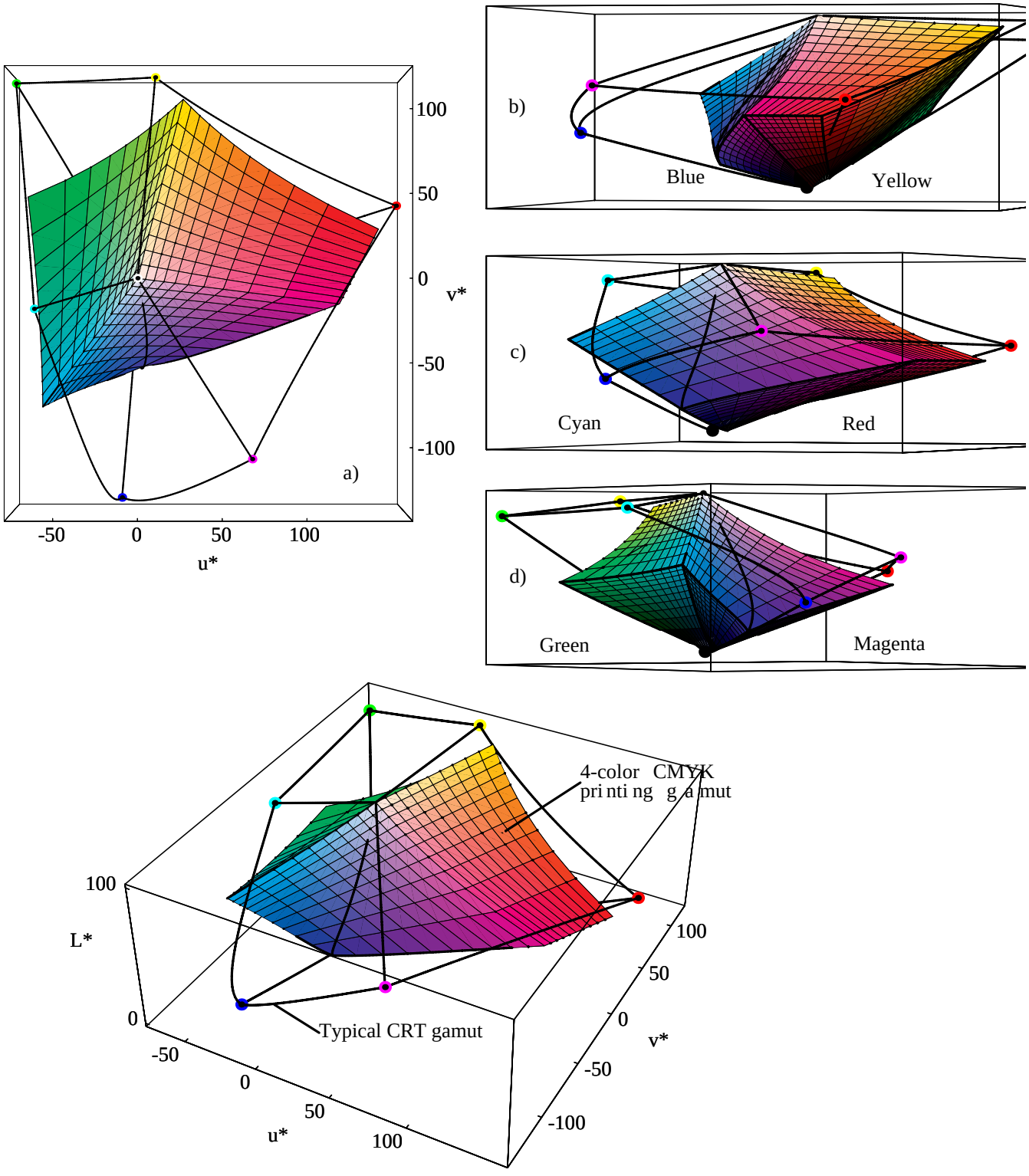
W: Blanc
R: Rouge
G: Vert
B: Bleu
Cy: Cyan
M: Magenta
Y: Jaune

4-Colour Printing Gamut in CIE-XYZ space

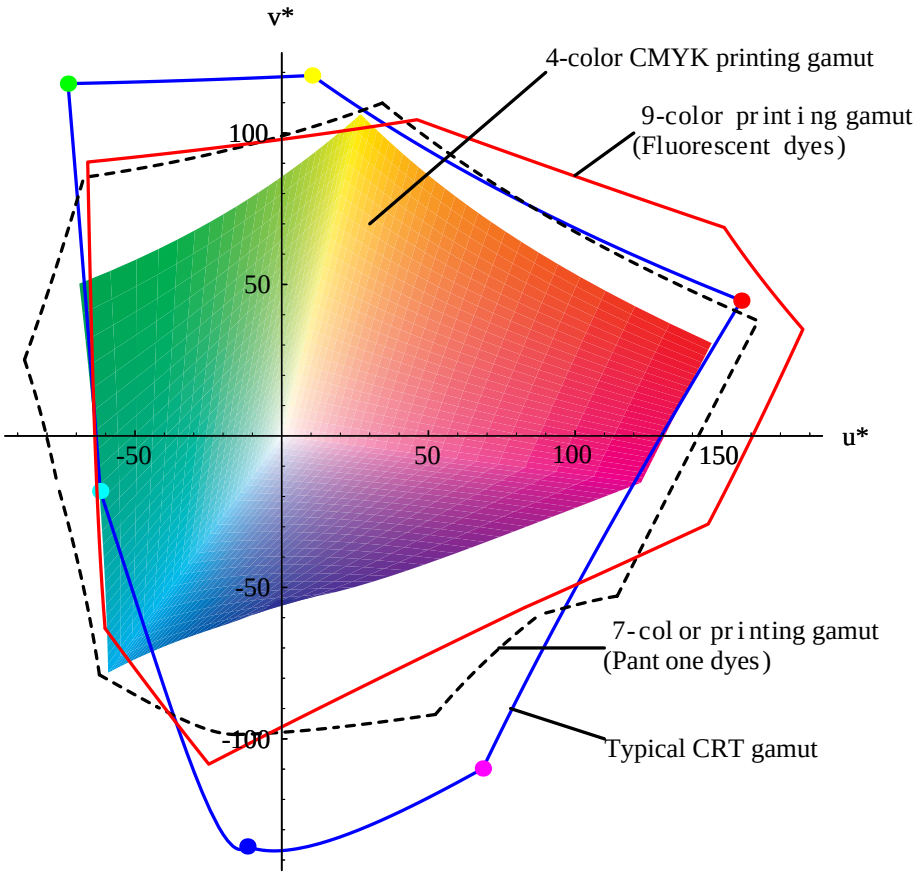




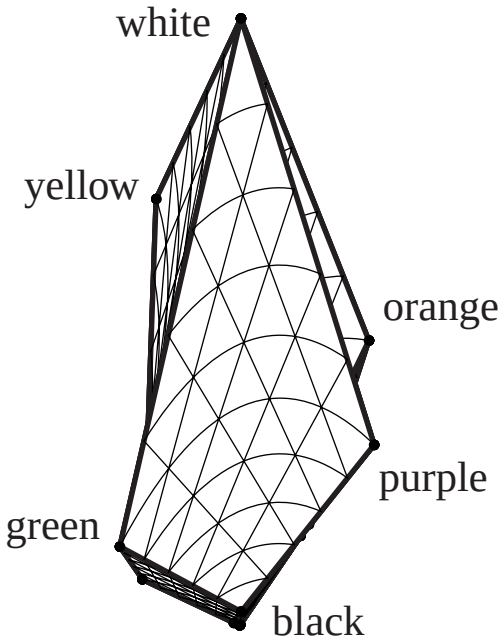
4-Colour Printing Gamut in L*u*v* space

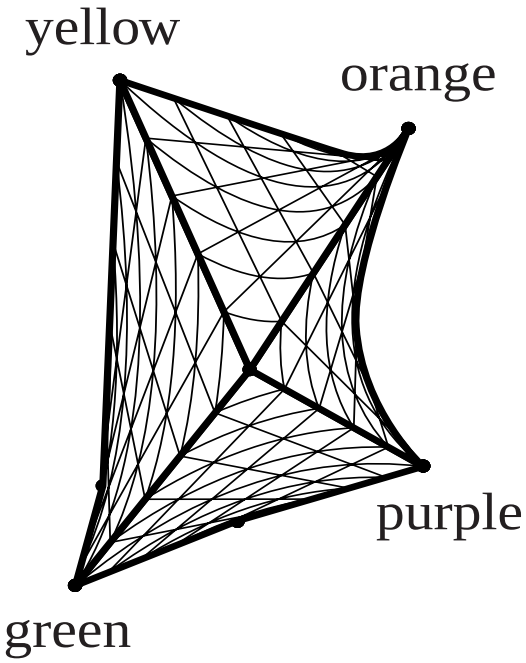


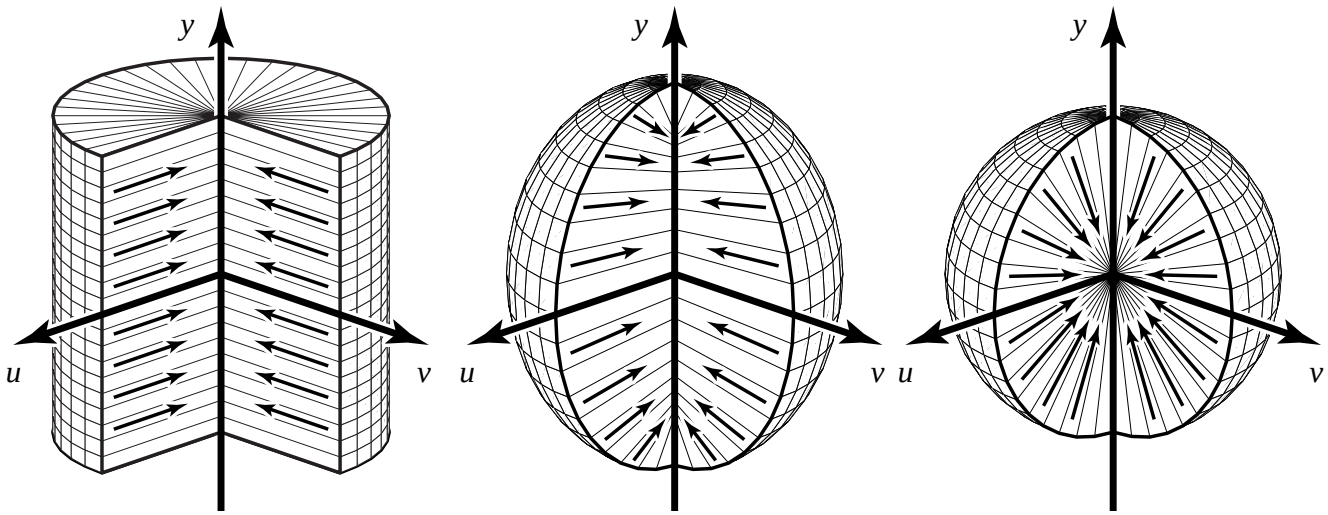
Enlarged Printing Gamut Using Non-Standard Colours



Gamut Mapping

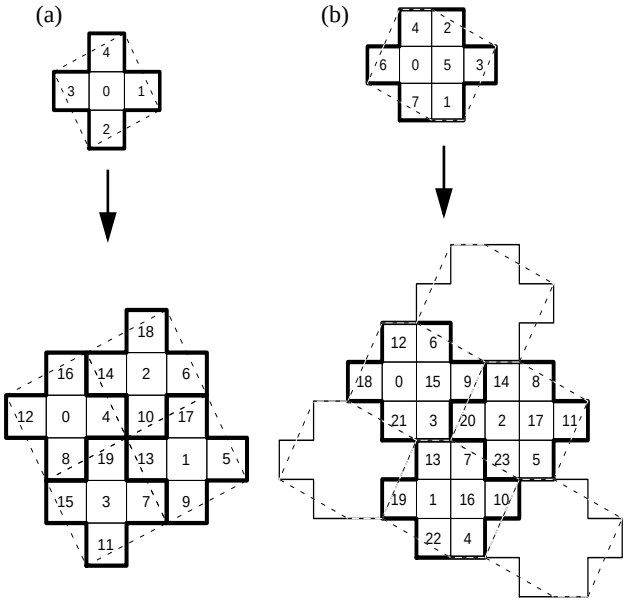




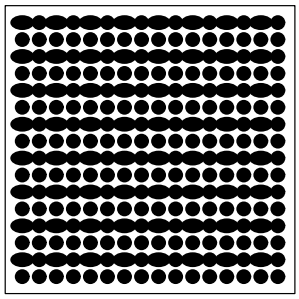


Halftonining for Multi-Level Devices. Dithering.

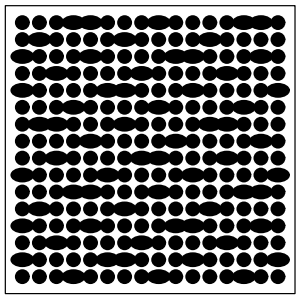
Recursive generation of a parallelogram (a) and hexagonal (b) dispersed dither tiles



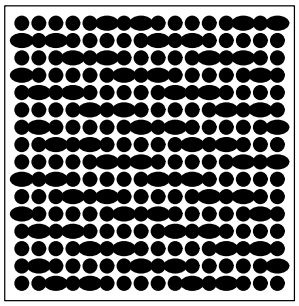
Breaking the horizontal bands produced by elliptic dot shapes with distributions of dither thresholds



(a) Bayer Dispersed Dither level i+2



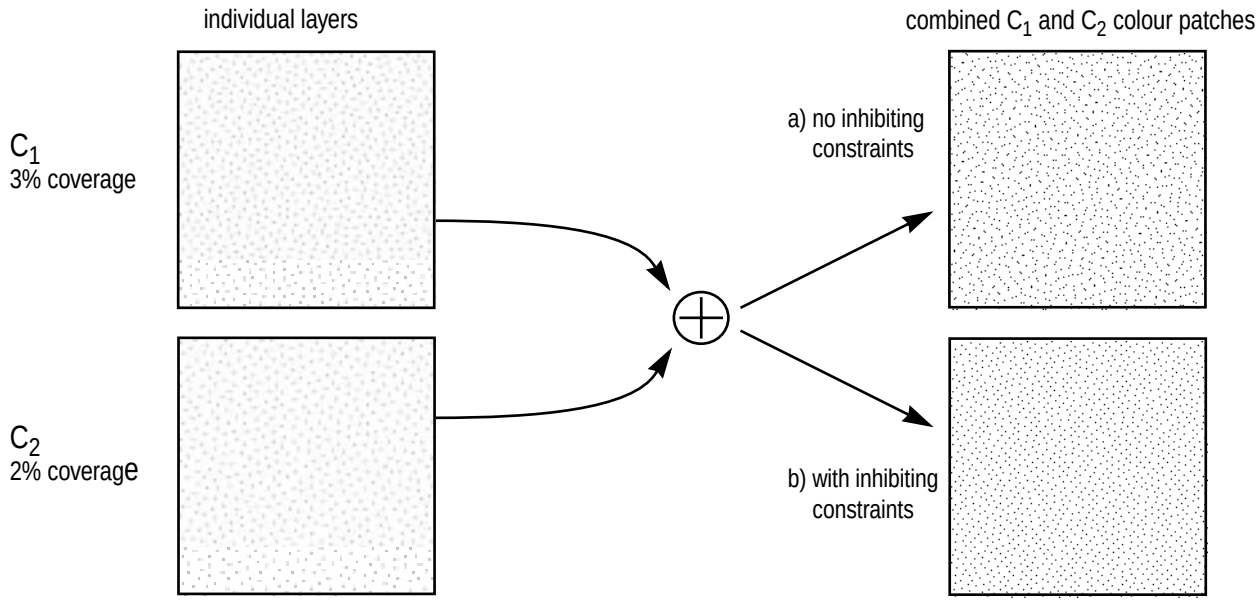
(b) Parallelogram Dispersed Dither level i+2



(c) HexagonalDispersed Dither level i+2

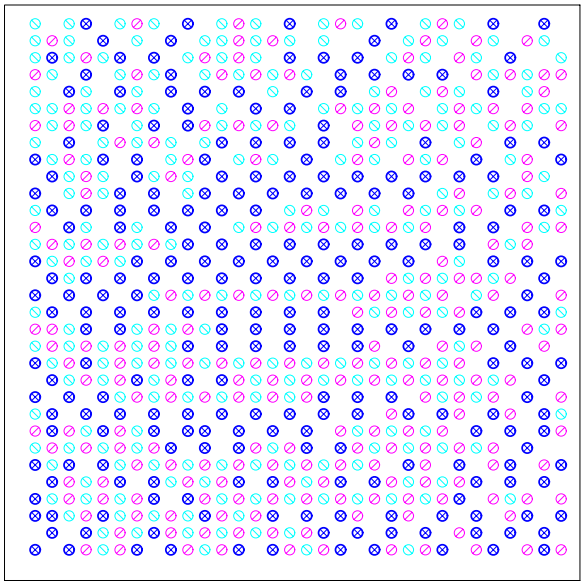
Halftonining for Multi-Level Devices. Error-diffusion.

Colour error-diffusion (a) without and (b) with constraints inhibiting dot over dot printing

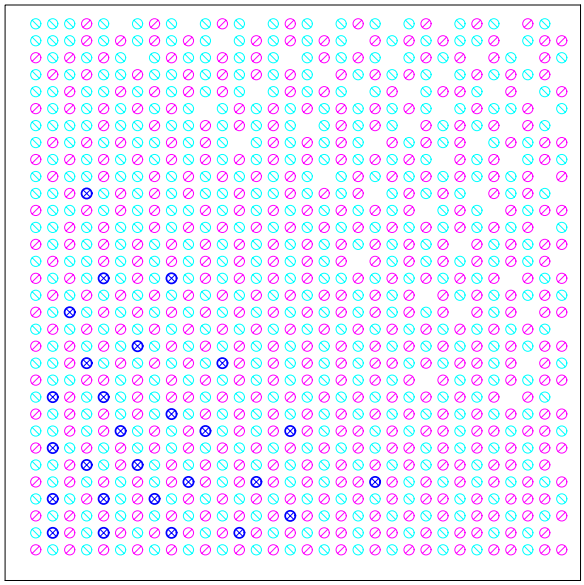


Bi-level colour error-diffused patch with surface coverages c1= 50%, c2=50% at the center and with ±12% coverage increase/decrease towards the edges

a)



b)



Two-dimensional representation of the white cyan magenta blue gamut and of corresponding error-diffusion output colours

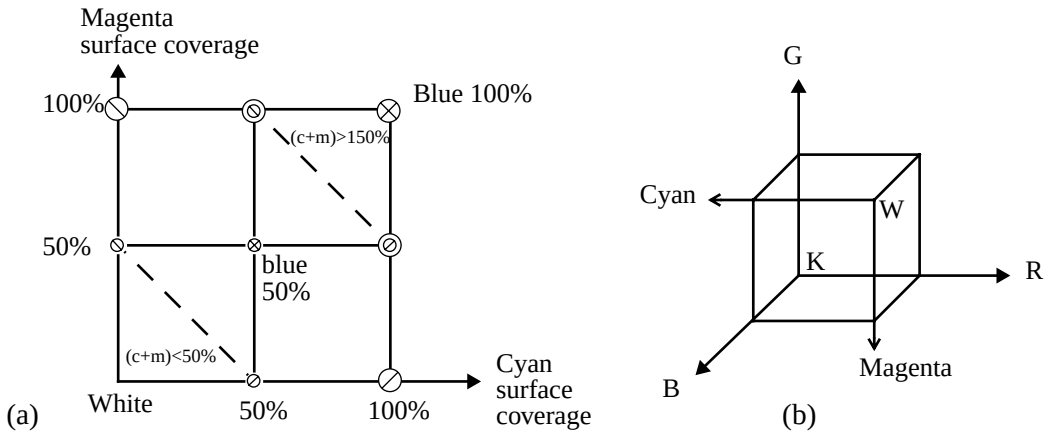
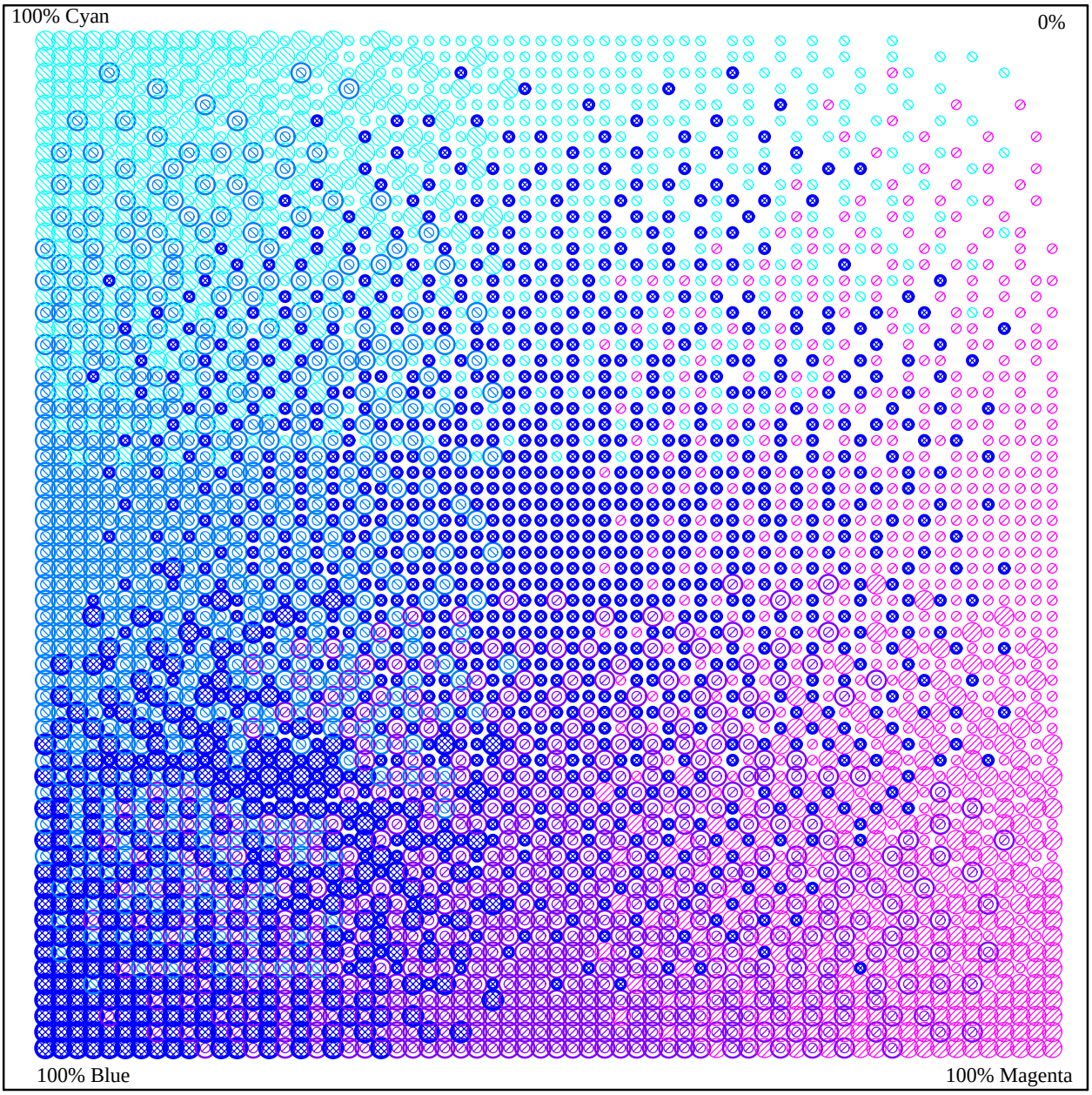


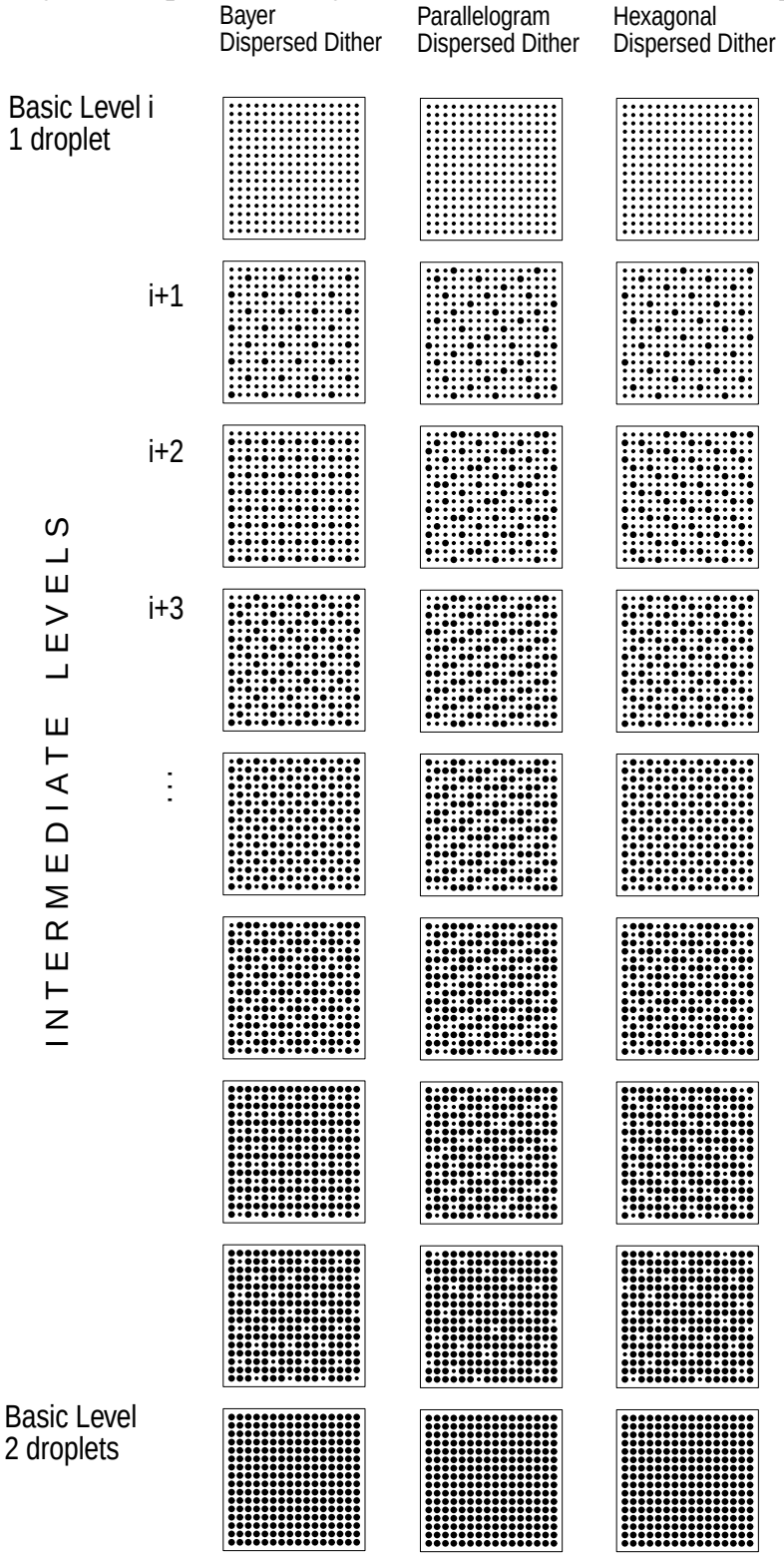
Table 1: Printable colours for variable dot size error-diffusion

Colour	label	droplets	symbol
White	White	no droplet	
Cyan 50%	c50%	one C-droplet	⊘
Cyan 100%	c100%	two C-droplets	⃠
Magenta 50%	m50%	one M-droplet	⦸
Magenta 100%	m100%	two M-droplets	⃠
Blue 50%	c50%m50%	overlapped one C & one M droplet	⊗
CyanBlue	c100%m50%	overlapped two C & one M droplet	⊘
MagentaBlue	c50%m100%	overlapped one C and two M droplets	⦸
Blue 100%	cyan100%m100%	overlapped two C and two M droplets	⊗

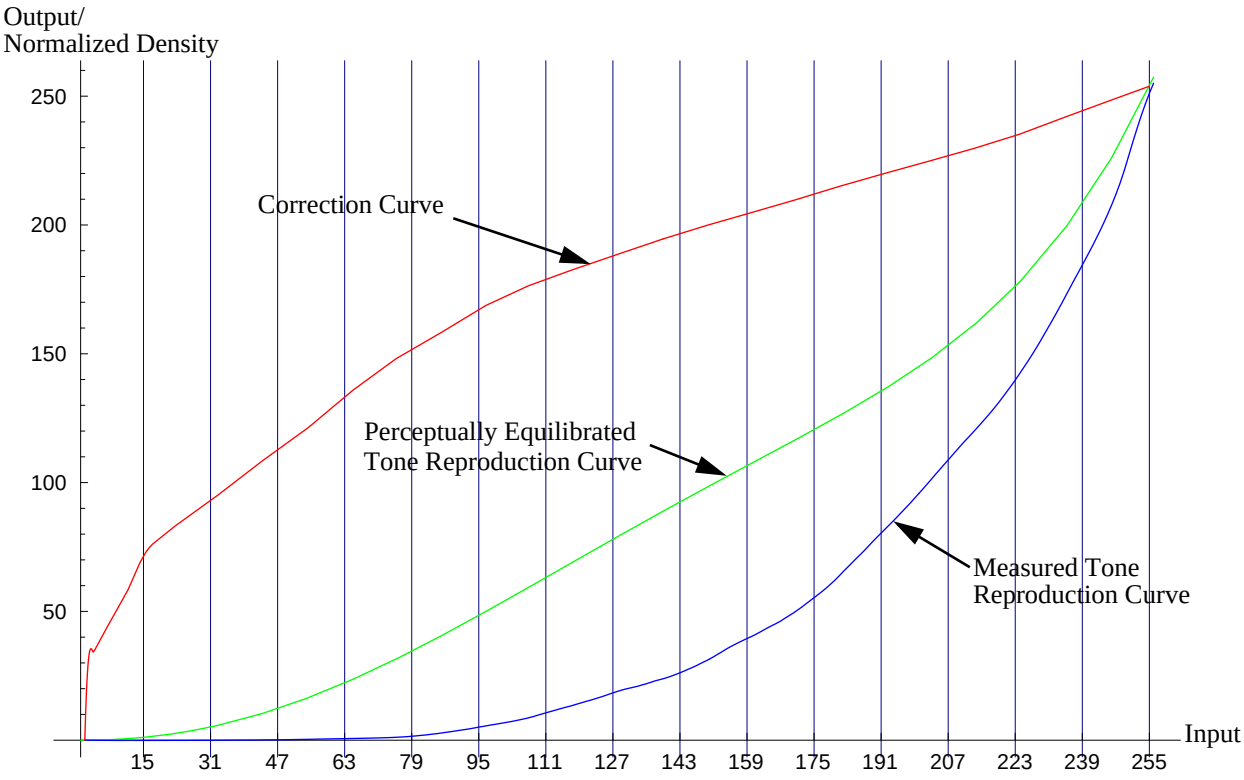
Variable dot size colour error-diffused cyan magenta wedge, with intensity-dependent inhibiting constraints (blue 50% allowed)



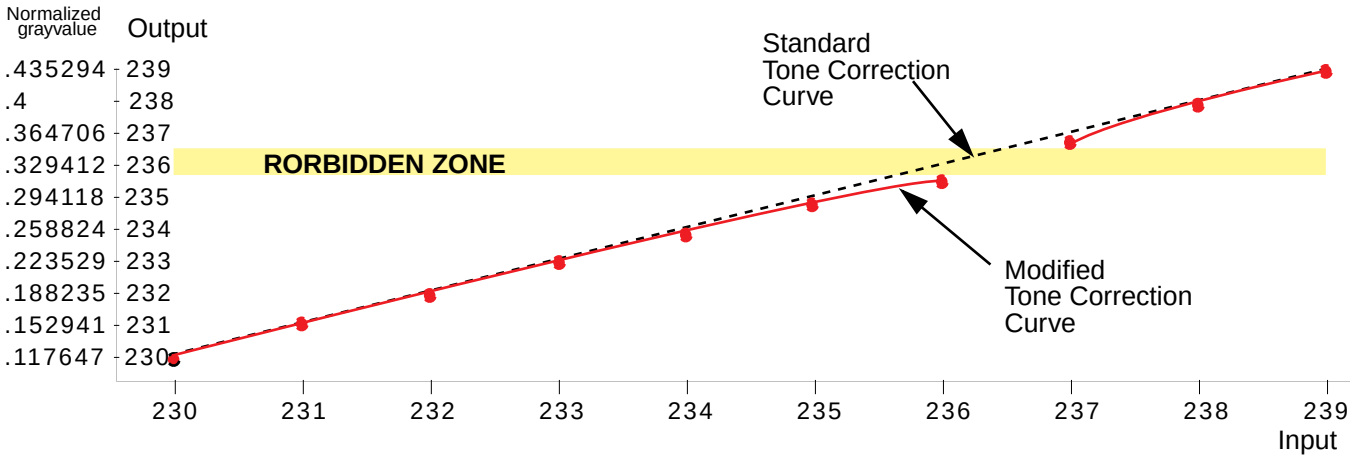
Intermediate intensity levels produced by dither tile based multi-level printing

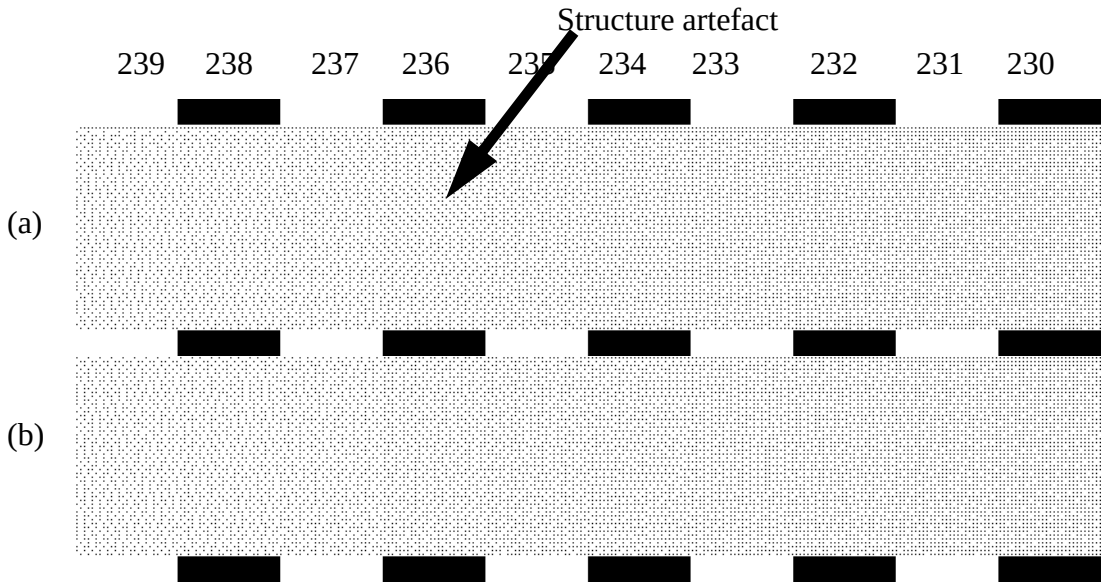


Tone Correction Curve

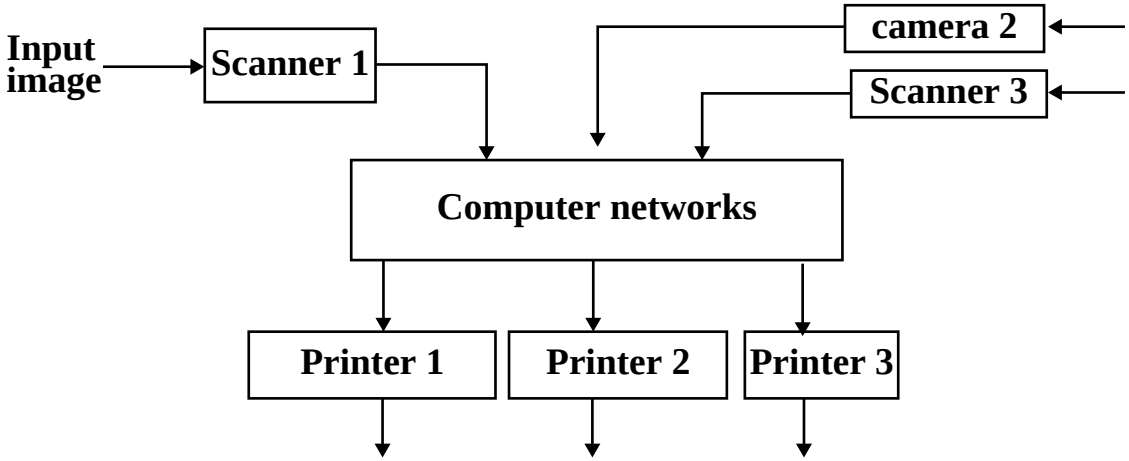


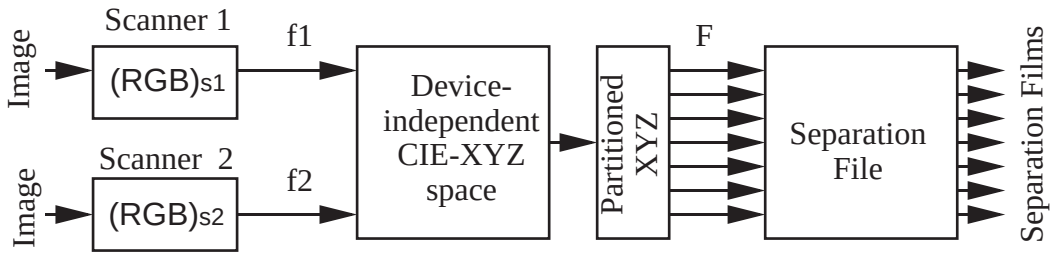
Avoiding Structure Artifacts



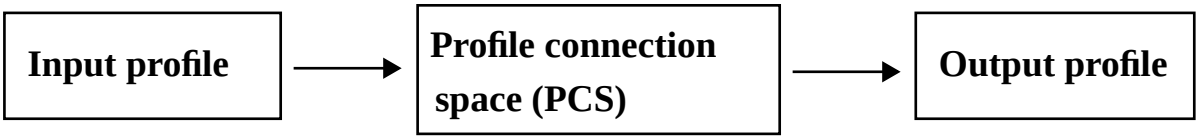


Calibration





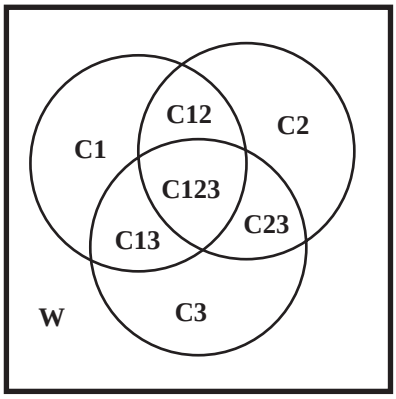
f1, f2: scanner calibrated RGB -> XYZ conversion function
F: calibrated separation function

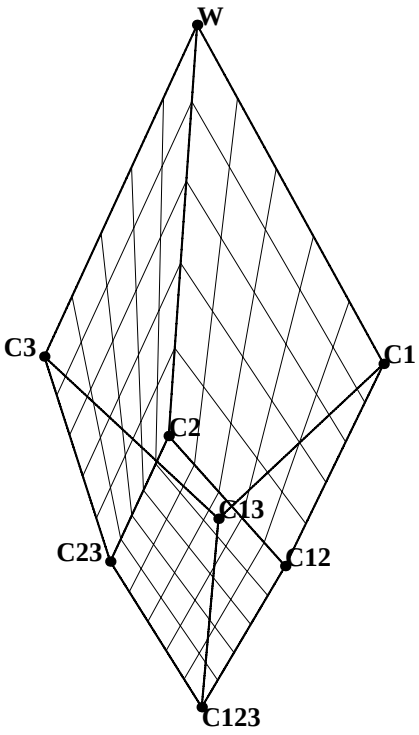


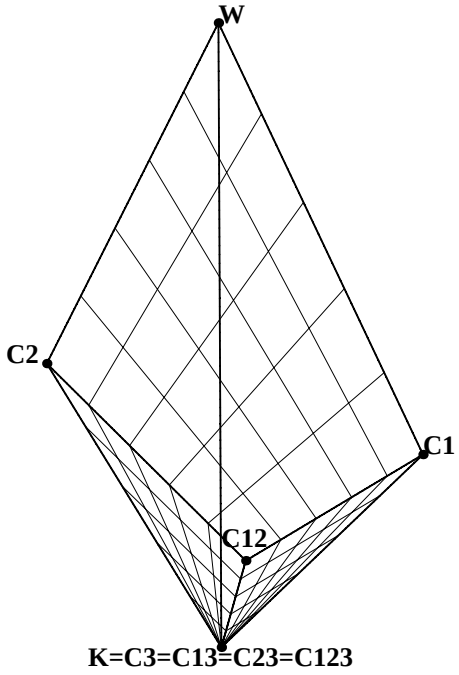
The ICC standard

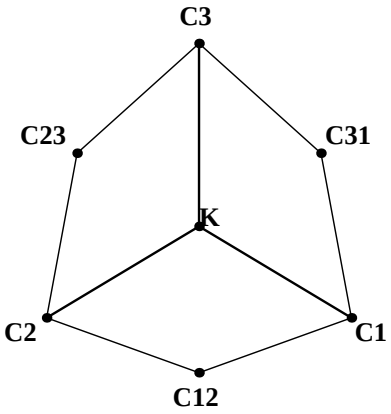
International Colour Consortium (http://www.color.org)

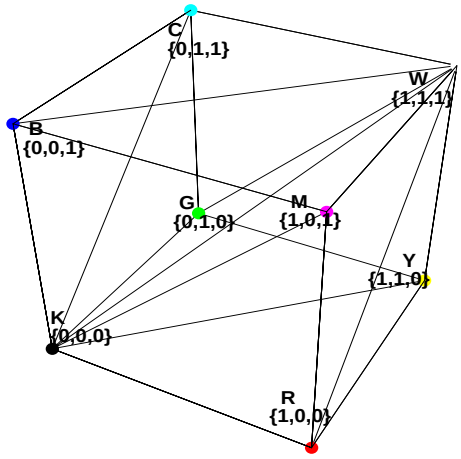
Calibration (cont.)

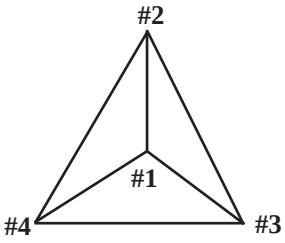


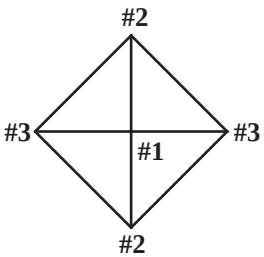


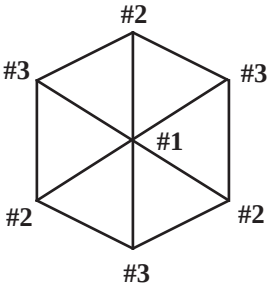




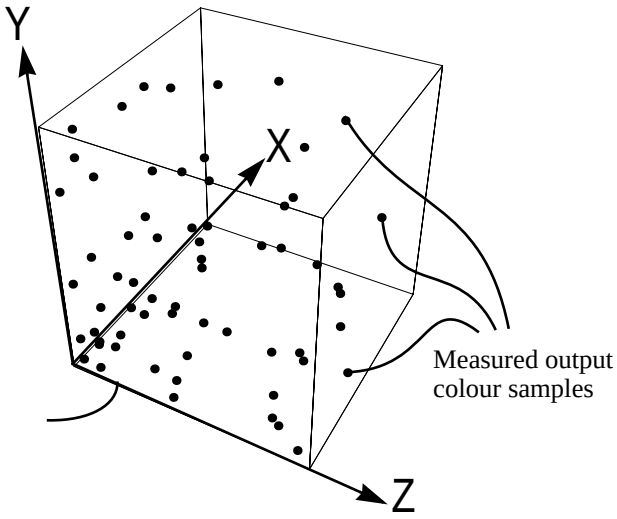


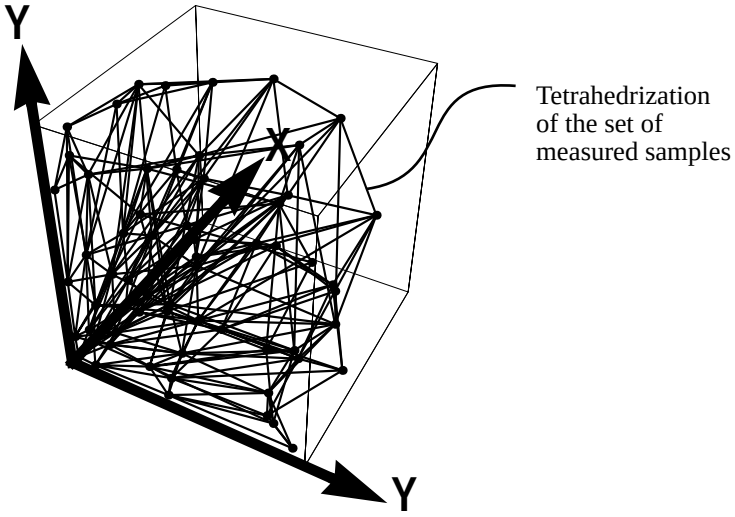


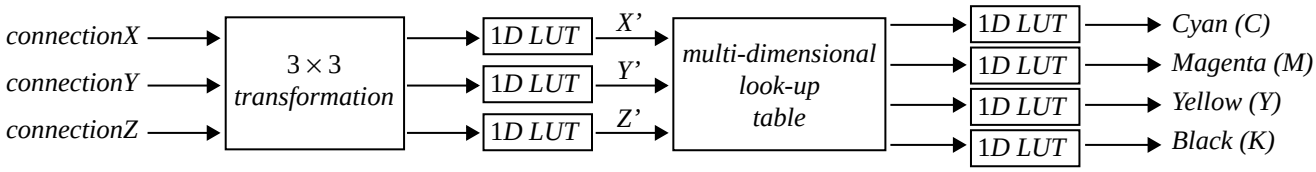




Calibration (cont.)







ICC output device profiles

Conclusions

- The choice between increasing printer's resolution and/or the number of colours should be the result of a trade-off between several criteria such as visual quality, cost, speed etc.

- Multi-color printing process may offer larger gamut compared with multi-level 4-ink process. As a counterpart, the calibration of a multi-color device may be more delicate.

- Multi-level/multi-color printing process requires specific halftoning technology, specific gamut mapping, specific ink-limit control, specific tone reproduction curve, and specific device calibration.

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