Digital and Analogue Photographic Parallels

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Image Pathway

Subject \rightarrow HVS (i) \rightarrow Camera \rightarrow Processing \rightarrow Visible Image \rightarrow HVS (ii) \rightarrow Interpretation
Tone and colour reproduction (1890s onwards)

Sensitometry
- The characteristic curve
- Speed of film
- Tone and colour reproduction

Artefacts
- Noise (graininess, granularity)
- Edge effects
Parallels (II) Si

Digital reproduction (1980s onwards)

Tone and Colour

- The characteristic curve
- Acceptability of reproductions

Artefacts

- Grain (noise) etc.
- Edge effects
- Contouring *et al*
Hurter & Driffield (1890) - Sensitometry

\[ D_T = \log_{10} \left( \frac{1}{\tau} \right) = \log_{10} \left( \frac{I_o}{I_t} \right) \]

Optical density as measure of Ag image:

Density is approximately linear with the concentration of image silver present.

Density is approximately linear with the visual effect of the image silver present.
Photographic Characteristic (I)

Diagram No. 7
Experiment No. 21.
Photographic Characteristic (II)

Diagram No. 8

- Experiment No 22
- Curve Calculated
- Experimental Evidence

Density

Exposure, Candle-Metre-Seconds
Digital Characteristic (II)

\[ y = 0.5781x + 0.8684 \]

\[ R^2 = 0.9941 \]
Nikon E5400 Digital Camera - TIFF image files

PC

CD ROM

PC, Adobe Photoshop

Monitor, sRGB
Photoshop & Image Evaluation

Data from images

- Image histogram gives large-area data
- Colorimetric data, CIE u’v’, CIELAB
- Image histogram gives small-area data
Tone Reproduction Studies
Histogram from Selected Area

Channel: Luminosity

- Mean: 147.41
- Std Dev: 3.07
- Median: 147
- Pixels: 22500

Level:
- Count:
- Percentile:
- Cache Level: 2
Colour Reversal Film

Reversal Colour Film

Visual Density, Dv

Log Relative Exposure
Camera TIFF to Monitor (sRGB)

Exposure Series, grey scale, ISO50

Visual Density vs. Corrected Log Relative Exposure

- White
- N8
- N6.5
- N5
- N3.5
- Black
Reversal Film and Digital Reproductions

Normalised Dv

Log Relative Exposure

Colour film
Digital
Camera TIFF to Monitor (sRGB)

ISO 50, 100, 200, 400 exposures

Visual Density vs. Log Relative Exposure for ISO 50, 100, 200, 400
Camera TIFF to Monitor (sRGB)

ISO 50 & 400 Exposure series, +2 to -2

Visual Density

Log Relative Exposure

0.9

50s
50
400s
400
Tone Reproduction
Silver and Digital Noise
Digital Noise

ISO50  N5

ISO1600  N8.5
Digital Noise

**Std Deviation of Density vs Image Density**

- For ISO 50:
  - \( y = 1.0775x - 0.0295 \)
  - \( R^2 = 0.9704 \)

- For ISO 400:
  - \( y = 1.9742x + 1.8443 \)
  - \( R^2 = 0.9629 \)
Photographic Emulsion Noise

Granularity: dye and silver images

\[ \sigma_a \times 10^3 \]

- Ag image
- Dye image

XP1
Silver Image Graininess

Graininess vs. Diffuse density graph for Ag Image.
Gretag Macbeth ColorChecker
Edge and Emulsion Response

Smoothed edge profiles and development conditions

- High definition developer
- General purpose developer
- Perfect edge image
Ag Edge Profile
Edge and CCD Response

Black bar - N5

Dv

Distance on screen (mm)
Sharpening:  N8 - black - N6.5

N8 - Blk bar - N6.5, no sharpening

Distance on screen (mm)

N8 - Blk bar - N6.5, sharpening

Distance on screen (mm)
Sharpness:  N8 - black - N6.5
Digitisation - Artefacts

- Quantisation errors
  - Contouring (low bit depth, high contrast subject)

- Edge effects

- Moire effects
Colour Reproduction
Human Photopic Colour Vision

Human Cone Responses

Relative Sensitivity

Wavelength (nm)

400 500 600 700

Blue Green Red

ρ β γ
Imaging System (Film)

ISO Daylight Film Sensitivities

- Blue: 400 nm
- Green: 500 nm
- Red: 600 nm

Rel. Spectral Sensitivity vs. Wavelength (nm)
Imaging System (Digital SLR)

![Graph showing the relative response of a Digital SLR imaging system across different wavelengths.]
Colour Gamut - Reversal Film

K14 gamut

- SpecLoc
- Red
- Green
- Blue
- Cyan
- Magenta
- Yellow
- sRGB
u'v' Chromaticity Chart: Digital camera
ISO50 exposure series

Spectral Locus
D65
50+2
50+1
50
50-1
50-2
Colour Gamut - Digital (400)

u'v' Chromaticity Chart: Digital camera
ISO400 exposure series
Gamuts - Digital & sRGB

Key
- Green: ISO 400 (+2)
- Light Blue: ISO 400
- Cyan: ISO 400 (-2)
- Purple: ISO 50 (+2)
- Magenta: ISO 50
- Red: ISO 50 (-2)
- Dotted Line: sRGB
D & A Parallels Exist

- Tone reproduction (D vs Log E)
- Colour reproduction (CIE u’v’ diagram)
- Fine detail
- Artefacts