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SI 675 Digitization for Preservation

Week 3 - Digitization Guidelines Today
Today’s Outline

1 Outline
2 Scanners
3 Specifications
4 FADGI
5 Metamorfoze

- Scanning technology
- Scanning specifications
- Federal Agencies Digitization Guidelines
- Metamorfoze benchmarks

“Image literacy (n): The ability to read, interpret and use generally accepted imaging results, to handle the corresponding performance information, to express ideas and opinions, to make decisions and solve related problems.”

Williams/Burns (2009)
What is an Image... and how is it characterized?

A two dimensional spatial structure of varying light levels and colors. It is characterized by measuring physically realizable light intensities over a two dimensional space. These variations can occur over short distances, like edges, (high frequencies) or larger distances or areas, like sky or facial features (low frequencies).
The Big Picture - General Imaging Steps -

input → Acquire → Process → Interpret or/and Display → output

**CAPTURE** Encode - Converting light to numbers

**DISPLAY** Decode - Converting numbers to light

“The Digital Image” An encoded proxy image

**Imaging Performance Metrics** indicate how an imaging system or component acts on, modifies or limits the effective optical characteristics of an input scene.

Once digitally captured, the image ceases to exist as light intensities. They are now encoded as N-bit (M channel) digital files. Because the encoding is easily manipulated, ISO imaging capture performance metrics attempt to trace the data back to the original scene input intensities (input referred) or expected output intensities (output referred).
What is a Digital Imaging System?

A collection of optical, software, or electronic functions that convert, encode, or otherwise act upon images or their optical or digital derivatives.

The performance of a digital capture system is influenced by all of the above in addition to operator training and environment.
Optical properties of objects

Density = \(-\log_{10}(\text{reflectance})\)

* In practice, it is often more convenient to specify in terms of density, especially for densities greater than 1.0

Reflective or transmissive hardcopy

Incident Illumination - 1000 units

- 1000 units reflected  
  1000 units incident  
  = 1.000 reflectance  = 0.0 density

- 100 units reflected  
  1000 units incident  
  = 0.1000 reflectance  = 1.0 density

- 10 units reflected  
  1000 units incident  
  = 0.0100 reflectance  = 2.0 density

- 1 unit reflected  
  1000 units incident  
  = 0.0010 reflectance  = 3.0 density
Know your Collection

- Typical density ranges for collection content -

B&W Photographic Paper
B&W Photographic Film
Kodachrome film
Color photographic paper
Q-13 target
Munsell papers
Motion picture print film
Non Photographic reflective material

Density

0  0.5  1  1.5  2  2.5  3  3.5  4  4.5
Types of Digital Capture Systems
- Scanners vs. Cameras -

- **Fully Integrated** — all capture components combined into a single plug-and-play scanner unit
  - Flatbed scanners – Epson ($), Creo IQSmart3 ($$$$)
  - Copy Stand – Zeutschel, I2S products, Stokes
  - Special Purpose - Kirtas, Treventus, and Qidenus

- **D-I-Y Copy stands** (i.e. camera-on-a-stick)
  - Camera Backs – Betterlight, Hasselblad, Sinar,
  - Digital SLRs – Canon EOS, Nikon
Popular Detector Arrangements

**Linear arrays** – one dimensional ordered arrangement of single detectors

**Area arrays** – two dimensional ordered arrangement of single detectors.

**Step and Repeat (Macro or Micro) area strategy** – capture and combine several area captures into a single large image.
Linear Arrays (Tri-linear)

- Three filtered (Red, Green, Blue) rows of sensors
- The sensor stares at the object in the row dimension and scans by the object in other direction. Sometimes called a pushbroom.
- Used in scan back cameras (e.g. BetterLight, PhaseOne FX, Seitz), flatbed scanners and most film scanners.
- Frequently have different performance behaviors in the two directions different directions

From: The Focal encyclopedia of photography
2-D Area Arrays
- Color Filter Array (CFA) pattern -

- Three filter mosaic pattern (Red, Green, Blue) of sensors. Sometimes other patterns are used but the “Bayer” pattern (shown here) is by far the most popular. Used in virtually all consumer and professional digital cameras.

- One shot /one layer, sparsely populated color capture. Fully populated color achieved by interpolation algorithms (demosaicing) or micro-stepping.

- Color filters integrated onto the sensor chip at manufacturing.

- Occasionally will have subtle checkerboard artifacts or color aliasing rainbows in final delivered image.

From: The Focal encyclopedia of photography
Guidelines Specifications - Raw Data

<table>
<thead>
<tr>
<th>Number</th>
<th>Document Name</th>
<th>Year</th>
<th>B/W DPI</th>
<th>B/W Bit Depth</th>
<th>col. Dpi</th>
<th>Color Bit Depth</th>
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<td>3</td>
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<td>300-800</td>
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<td>2001</td>
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<tr>
<td>11</td>
<td>CDL 01</td>
<td>2001</td>
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<td>8</td>
<td>600 ppi</td>
<td>24</td>
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<td>depends</td>
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<td>15</td>
<td>NARA 04</td>
<td>2004</td>
<td>400 to 800 ppi</td>
<td>8 to 16</td>
<td>400 to 800 dpi</td>
<td>24 to 48</td>
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<tr>
<td>16</td>
<td>CDL 05</td>
<td>2005</td>
<td>4000-8000 pixels</td>
<td>8</td>
<td>4000-8000 pixels</td>
<td>24</td>
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<tr>
<td>17</td>
<td>LoC 06</td>
<td>2006</td>
<td>300 ppi (or device maximum)</td>
<td>8</td>
<td>300 ppi (or device maximum)</td>
<td>24</td>
</tr>
<tr>
<td>18</td>
<td>NC Echo 07</td>
<td>2007</td>
<td>4000 pixels or 600 dpi</td>
<td>8</td>
<td>4000 pixels or 600 dpi</td>
<td>24</td>
</tr>
<tr>
<td>19</td>
<td>BCR 08</td>
<td>2008</td>
<td>400 to 800 ppi</td>
<td>16</td>
<td>400 to 800 dpi</td>
<td>48</td>
</tr>
</tbody>
</table>

Have Guidelines Changed over Time?

\[ BQI \text{ Volume} = (dpi^2_c \times \text{depth}_c) + (dpi^2_g \times \text{depth}_g) \times 0.0001 \]

Image Performance vs. Imaging Quality

- **Imaging Performance**: Objectively measured behaviors of an imaging system in preserving information of the original object.
  - For example: Tone response, Resolution, Noise, Color error, White balance, Light falloff (uniformity)
  - Imaging Capability – Imaging Performance under optimal conditions
    - Operator
    - Environment
    - Ease of use
  - Both Accuracy and Precision are measurement requirements

- **Image Quality**: Task, appearance, or use case dependent measure. It is almost always some weighted combination of imaging performance metrics.
  - Aerial reconnaissance – high resolution and low noise
  - Health Imaging – tone control, low noise, resolution is dependent on task
  - Document Imaging – OCR accuracy
  - Consumer Imaging – Memory-color saturation, moderate resolution
    - Sharpness
    - Graininess
    - Colorfulness
    - Naturalness
Measurement Requirements

Measurements usually require some level of both accuracy and precision.

- Accuracy: average error from an aim
- Precision: variability about the average reading

Factors that influence measurements

- Location on platen
- Image processing
- Spatial sampling
- Image noise
- Environment
- Operator skill

Performance is more about consistency (precision) than accuracy. In imaging, accuracy is often not absolute but rather a preference.
Digitization Guidelines

The Technical Guidelines for Digitizing Cultural Heritage Materials
Updated by Working Group | August 24, 2010

Creation of Raster Image Master Files represents shared best practices followed by agencies participating in the Federal Agencies Digitization Guidelines Initiative (FADGI) Still Image Working Group for digitizing cultural heritage material.

Content Categories and Digitization Objectives
Updated | September 3, 2009

Description of 8 categories and 23 subcategories of printed matter, manuscripts, and pictorial materials. The Working Group’s recommended specifications for the digital reformatting of these items will be defined and evaluated in terms of objectives. Why are the copies being made? What uses will these copies support? Do considerations vary from one category to another? The objectives are presented here as use cases.

Embedding Metadata in Broadcast WAVE Files
Approved | September 15, 2009

The Working Group has developed the BWF MetaEdit tool to support users of the specification, as well as providing other functionality for work with WAVE and Broadcast WAVE files. Information about the tool is provided below.

TIFF Image Metadata
Approved by Working Group | February 10, 2009

A new recommended guideline accompanies a future metadata set in
Federal Agencies Digitization Guidelines

- Technical foundation in image science
- Workflow for purposes of accomplishing imaging aims.
  - Aim points
  - Color management
- Aims as specifications by record types
- Other elements of the document that make it comprehensive
  - Metadata (METS)
  - Quality management
  - Photograph digitization for preservation

http://www.digitizationguidelines.gov/
**Vocabulary**  
- staying dry in a storm of vernacular idioms -
Important Imaging Characteristics

A number of these categories have ISO standards that define the metrology practice. Though intended for digital imaging devices their basis was derived from decades of analog (e.g., film) imaging experience.

Primary Imaging Performance Functions

- **Signal** — Any response that provides valued information
  - Large area response to light
  - OECF - Opto-Electronic Conversion Function
  - Spatial proximity behavior
    - Spatial Frequency Response – SFR (or MTF)

- **Noise** — Any response that detracts from a desired signal
  - Light intensity distortions – Total noise
  - Geometric/Spatial distortions
### Imaging Performance Framework


<table>
<thead>
<tr>
<th>Primary Functions</th>
<th>Signal</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OECF</strong> (Opto-Electronic Conversion Function)</td>
<td><strong>SFR</strong> (Spatial Frequency Response)</td>
<td><strong>Light Intensity Distortion</strong></td>
</tr>
<tr>
<td><strong>NPS</strong> (Noise Power Spectrum)</td>
<td><strong>Geometric Distortion</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Derived Metrics</th>
<th>Signal-to-Noise Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed / Sensitivity</td>
<td>Tonal / Exposure</td>
</tr>
<tr>
<td>White Balance / Neutrality</td>
<td>Sampling Rate</td>
</tr>
<tr>
<td>Color Encoding Error</td>
<td>Resolution</td>
</tr>
<tr>
<td>Linearity</td>
<td>Acutance</td>
</tr>
<tr>
<td>Flare</td>
<td>Depth of Focus</td>
</tr>
</tbody>
</table>

#### Total Noise
- **Temporal**
- **Fixed Pattern**
- **Chroma Noise**
- **Random (Non-deterministic)**
- **Banding/Skewering (Non-deterministic)**
- **Defects (Deterministic)**
- **Color Uniformity (Deterministic)**
- **Spatial SR Uniformity (Deterministic)**
- **Regional Artifacts (Deterministic)**
- **Aliasing (Deterministic)**
- **Pitching/Flicker (Deterministic)**

*While imaging noise is generally considered to be of a random or stochastic granular nature (e.g., photographic film grain), it can actually take many forms. We have chosen to categorize it in both by its deterministic and stochastic behaviors.*
**SIGNAL**

Any response that provides valued information

<table>
<thead>
<tr>
<th>Primary Functions</th>
<th>Derivative Metrics</th>
<th>Related Descriptive Term</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity ISO 12232</strong></td>
<td>Sensitivity</td>
<td>Responsiveness, Speed, Exposure Index (EI)</td>
</tr>
<tr>
<td><strong>Tone and Exposure</strong></td>
<td>Tone and Exposure</td>
<td>Too dark/light, Under/over exposed, No shadow/highlight detail, Clipping, Contrast, Exposure Accuracy, Gamma</td>
</tr>
<tr>
<td><strong>White Balance/Neutrality</strong></td>
<td>White Balance/Neutrality</td>
<td>Color cast, Gray balance</td>
</tr>
<tr>
<td><strong>Color Encoding Error</strong></td>
<td>Color Encoding Error</td>
<td>Over/under saturated colors, Color balance is wrong, Memory colors are not correct, Color Accuracy, Color Saturation</td>
</tr>
</tbody>
</table>

**Definition:**
- **Sensitivity ISO 12232**: The reciprocal of the amount of light necessary to achieve a desired output response.
- **Tone and Exposure**: Characteristic behavior of large area digital output (response, count value) to spectrally neutral input stimuli (gray patch).
- **White Balance/Neutrality**: Equivalence of large area color channel output responses to a range of spectrally neutral input stimuli.
- **Color Encoding Error**: The difference between selected physically measured input colors and their intended rendering from a given color space.

**ISO 22028-1**
**SIGNAL**

Any response that provides valued information

<table>
<thead>
<tr>
<th>Primary Functions</th>
<th>MTF - Modulation Transfer Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitions: 1) A descriptor of an imaging system's ability to maintain the relative contrast of input stimuli of a given spatial frequency. 2) A spatial frequency descriptor of an imaging system's ability to maintain the relative contrast of features within a given spatial proximity.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Derivative Metrics</th>
<th>Sampling Rate</th>
<th>Resolution</th>
<th>Sharpening</th>
<th>Acutance</th>
<th>Flare</th>
<th>Depth of Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong></td>
<td>The reciprocal of the center-to-center distance between closest adjacent pixels. The number of samples per unit distance.</td>
<td></td>
<td><strong>Definition:</strong></td>
<td>Amplification of the SFR by means of image processing to achieve sharper appearing images</td>
<td><strong>Definition:</strong></td>
<td>A skirtly or wide spreading of light.</td>
</tr>
<tr>
<td>Megapixels</td>
<td>Blurred</td>
<td>Oversharpening (haloing, garish edges)</td>
<td>Sharp</td>
<td>Low contrast</td>
<td>Depth of field</td>
<td></td>
</tr>
<tr>
<td>Dots per inch (dpi)</td>
<td>Soft</td>
<td>Snap</td>
<td>Sharp</td>
<td>Hazy</td>
<td>Circle of confusion</td>
<td></td>
</tr>
<tr>
<td>Pixels per inch (ppi)</td>
<td>Sharp</td>
<td>Edgy, Sharp, Crisp</td>
<td>Edge enhancement</td>
<td>Ghosting</td>
<td>Focus tolerance</td>
<td></td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>In/Out of focus</td>
<td>Edge enhancement</td>
<td>Unsharp masking</td>
<td>Veiling flare</td>
<td>Hyperfocal distance</td>
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<tr>
<td>Spherical aberration</td>
<td>Spatial detail</td>
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<td></td>
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</tbody>
</table>

---
**NOISE**

Any response that detracts from a desired signal
**NOISE**

Any response that detracts from a desired signal

---

### Geometric/Spatial Distortion

**Definition:** The deviation of any imaged point from its intended or aim spatial position relative to the input object.

<table>
<thead>
<tr>
<th>Engineering Metric</th>
<th>Field height diagram (deterministic)</th>
<th>Regional (deterministic)</th>
<th>Color Misregistration (deterministic)</th>
<th>Aliasing (deterministic)</th>
<th>Spatial SFR uniformity (luminance) (deterministic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derivative Metrics</td>
<td>Definition: A change in magnification of an imaged object as a function of field position.</td>
<td>Definition: A locally varying deviation in intended spatial position of an imaged object.</td>
<td><strong>Definition:</strong> color-to-color spatial dislocation of otherwise spatially coincident color features of an imaged object.</td>
<td><strong>Definition:</strong> A sampling effect that leads to spatial frequencies being falsely interpreted as other spatial frequencies.</td>
<td><strong>Definition:</strong> A difference in luminance SFR as a function of optical field position.</td>
</tr>
<tr>
<td>Related descriptive term</td>
<td>Pinch, Barrel, TV distortion, Field Curvature, Skew, Keystone</td>
<td>Wobble, Jitter</td>
<td>Colored edges, Chromatic aberration, Lateral chromatic error (LCE)</td>
<td>Jaggy, Moiré, Pinxiation, Potential for aliasing</td>
<td>Blurred or soft look near corners of image, Spherical Aberration, Coma</td>
</tr>
</tbody>
</table>

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Metamorfoze

- A major project of the Koninklijke Bibliotheek, National Library of the Netherlands

- Specifies “technical criteria and tolerances for preservation imaging”

- Input oriented and relate to the image quality of the “first image” only: preservation master

- Designed for Universal Test Target (UTT)
  - [http://www.universalittesttarget.com/](http://www.universalittesttarget.com/)
Image Engineering Dietmar: http://www.universalittesttarget.com/
References

Thank you!

Paul Conway
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School of Information
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www.si.umich.edu