A Handheld Image Analysis System for Portable and Objective Print Quality Analysis

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Objectives

• **Expansion of Imaging (Concept of ICJ2007)**

  Measurement technology is critical to the advancement of the science and technology of imaging.

• **Democratization of Objective Image Quality Analysis**

  Our goal is to bridge the gap between sophisticated image analysis in the laboratory and the need for a practical tool for EVERYDAY USE by EVERYONE.
Requirements

• **Functional** – calibrated, accurate, predictive, utilizes international and industry standards, …

• **Easy-to-Use** – simple operation even for the most sophisticated analyses: quick response, easy reporting, with specialized expertise built-in.

• **Portable and Affordable** - compact, light weight, and low cost

• **Flexible** – meets diverse measurement needs

• **Upgradeable** – capable of staying with the state-of-the-art at all times
Challenges

From the laboratory ...  
(expensive, complex)  

to portable, personal use  
(low cost, easy-to-use)  

HOW?
Hardware Solution

• Compact design & light weight
  – ~350g
• USB 2.0 interface to PC
  – No battery needed
• Interchangeable optics:
  – Different resolution & FOV
  – Different illumination geometry & spectral characteristics
• Built-in calibration
  – Grey level & spatial dimensions
• Processing capabilities
Optical Modules

- Fixed focus
- Multiple resolution modules - Hi & Lo
- 45/0, coaxial, ...
- Reflective & transmissive
- Visible, IR & UV

High Resolution
5 μm/pixel
3.2mm x 2.4mm

Low Resolution
37.5 μm/pixel
24mm x 18mm

Visible

UV Fluorescence

Security printing, forensic and other novel applications
Why Different Magnifications (1)

To improve correlation with human perception:

**Table:**

<table>
<thead>
<tr>
<th>Metric</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>72.7</td>
<td>73.2</td>
</tr>
<tr>
<td>L*</td>
<td>13.20</td>
<td>13.75</td>
</tr>
<tr>
<td>a*</td>
<td>10.29</td>
<td>12.78</td>
</tr>
<tr>
<td>Graininess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>7.68</td>
<td>8.70</td>
</tr>
<tr>
<td>a*</td>
<td>11.8</td>
<td>13.3</td>
</tr>
<tr>
<td>b*</td>
<td>20.3</td>
<td>12.8</td>
</tr>
<tr>
<td>Mottle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>1.17</td>
<td>1.46</td>
</tr>
<tr>
<td>a*</td>
<td>1.13</td>
<td>1.33</td>
</tr>
<tr>
<td>b*</td>
<td>1.22</td>
<td>1.80</td>
</tr>
</tbody>
</table>

**Legend:**

- Low Resolution Optics
- Large Field of View
Why Different Magnifications (2)

To provide machine diagnostic information:

<table>
<thead>
<tr>
<th>Dot Metrics</th>
<th>Mean A</th>
<th>Mean B</th>
<th>Stdev A</th>
<th>Stdev B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (mm²)</td>
<td>0.005</td>
<td>0.005</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>0.078</td>
<td>0.077</td>
<td>0.007</td>
<td>0.014</td>
</tr>
<tr>
<td>Perimeter (mm)</td>
<td>0.247</td>
<td>0.270</td>
<td>0.024</td>
<td>0.076</td>
</tr>
<tr>
<td>BoxRatio</td>
<td>0.563</td>
<td>0.747</td>
<td>0.143</td>
<td>0.183</td>
</tr>
<tr>
<td>Circularity</td>
<td>0.103</td>
<td>1.221</td>
<td>0.045</td>
<td>0.317</td>
</tr>
</tbody>
</table>

High Resolution Optics
Small Field of View
Calibration (1)

• Grey level (Reflectance and Density)
  – Use a test chart with calibrated CMYK tone scales (traceable)
  – Obtain camera RGB values
  – Obtain correlation between camera RGB and calibrated reflectance % (CMYK)
  – Convert reflectance % to optical density (for Status A, T, DIN and DIN NB)

• Color (L*a*b*)
  – Use a test chart with known sRGB values
  – Convert camera RGB to sRGB
  – Convert sRGB to L*a*b*
Calibration (2)

• Spatial Dimensions (x and y)
  – Use a calibrated (traceable), precision Ronchi ruling (chrome on glass)
  – Obtain x and y resolution in μm/pixel
Software Solution

- Intuitive user interface
- Analysis in real time or on saved images
- Mostly “one-click” to obtain useful results

- Efficient data & image interface to Excel or database
- Expandable analysis toolbox, e.g. A - basic, B - advanced

Analytical Tools

FOV (Image)

ROI

Numerical Results

Graphical Results
Analysis Toolbox (1)

- Dot quality (dot gain, dot shape and placement)
- Line and edge quality (width, blurriness, raggedness, contrast, fill and darkness – ISO13660)
- Text quality (stroke quality, fidelity, uniformity)
- Color adjacency and inter-color bleed
- Image noise (graininess and mottle – ISO13660)
- Banding, streaking, … (NPS – Noise Power Spectrum)
- Inkjet satellites, toner background, voids, ghosting …
Analysis Toolbox (2)

- Spatial Frequency Response ("slant edge" technique ISO12233) and Resolution
- Color registration error ("slant edge" technique)
- Profile and histogram tools
- Color channel viewing tools
- Density and color
- OCR (optical character recognition)
- Colorant % coverage
- Gloss and DOI
Applications

• **Engineering and Machine Diagnostics**
  – (e.g., machine chatters, unsteady paper feed, inkjet printhead misfiring, laser scanner instability, thermal or LED printhead non-uniformity, …)

• **Objective Image Quality vs. Perceptual Quality**
  – Tone and color reproduction
  – Sharpness and details
  – Image artifacts (defects)
  – Gloss and DOI (Distinction of Image)
Application Example (1) – Inkjet Print Head Diagnostics

Jetting Pattern

Analysis Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Diameter, Mean (µm)</th>
<th>39.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dots</td>
<td>104</td>
<td>Placement Error, Mean (µm)</td>
<td>20.7</td>
</tr>
<tr>
<td>Missing Dots</td>
<td>2</td>
<td>Diameter, Stdev (µm)</td>
<td>4.1</td>
</tr>
<tr>
<td>Extra Dots</td>
<td>6</td>
<td>Placement Error, Stdev (µm)</td>
<td>33.6</td>
</tr>
<tr>
<td>Spacing--Horizontal (µm)</td>
<td>351.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacing--Vertical (µm)</td>
<td>253.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High Resolution Optics Dot Tool
Application Example (2a)

Printer Benchmarking, A vs B

Two High Speed Color Electrophotographic Printers
Application Example (2b)
Tone Reproduction & Image Noise

- “A” & “B” have similar tone reproduction
- Image noise mostly higher in “B” and is dependent on Lightness (L*)

Low Resolution Optics Area Tool

Tone Reproduction:

Graininess:

Graininess in L' Unit
Application Example (2c)
Image Noise: ISO13660 Graininess/Mottle & NPS Analysis

Low Resolution Optics

<table>
<thead>
<tr>
<th>Illuminant Observer</th>
<th>D65 2°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Tile Size [μm]*</td>
<td>37.5</td>
</tr>
<tr>
<td>Mottle Tile Size [μm]*</td>
<td>299.6</td>
</tr>
</tbody>
</table>

*ISO-13660

<table>
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<tr>
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<tr>
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<td></td>
<td>b*</td>
<td>1.22</td>
</tr>
</tbody>
</table>

NPS Tool

Area Tool
Application Example (2d)
Sharpness & Details: Line Quality (ISO13660)

High Resolution Optics – Line Tool

- “A” has significant problem in writing thin lines correctly.
- Edge raggedness difference is small and imperceptible.
Application Example (2e)

Text Quality – Dot & Line Tools

High Resolution Optics – Line Tool

<table>
<thead>
<tr>
<th>Character Quality Attributes</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Stroke Width (μm)</td>
<td>398.5</td>
<td>363.9</td>
</tr>
<tr>
<td>Stroke Darkness (OD)</td>
<td>1.07</td>
<td>1.06</td>
</tr>
<tr>
<td>Stroke Contrast</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Edge Raggedness (μm)</td>
<td>4.03</td>
<td>3.61</td>
</tr>
<tr>
<td>Area (mm²)</td>
<td>3.17</td>
<td>2.75</td>
</tr>
<tr>
<td>Perimeter (mm)</td>
<td>20.62</td>
<td>22.12</td>
</tr>
<tr>
<td>Circularity</td>
<td>10.71</td>
<td>14.19</td>
</tr>
</tbody>
</table>

- “A” appears much bolder than “B” as indicated by Stroke Width & Character Area.
- Edge raggedness difference is small and imperceptible.
Application Example (2f)

Resolution & MTF (SFR Tool)

- The SFR tool (Slant Edge ISO12233) conveniently provides MTF information.
- “A” has slightly higher MTF than “B”.

High Resolution Optics – SFR Tool

![Image](image_url)
Application Example (2g)

Background Analysis

High Resolution Optics – Background Tool

<table>
<thead>
<tr>
<th>Background Metrics</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>18</td>
<td>118</td>
</tr>
<tr>
<td>Area (µm²)</td>
<td>278.0</td>
<td>363.1</td>
</tr>
<tr>
<td>Diameter (µm)</td>
<td>17.6</td>
<td>19.9</td>
</tr>
<tr>
<td>GS</td>
<td>1.36</td>
<td>4.54</td>
</tr>
</tbody>
</table>

- “GS” is a very useful metric for measuring Background, combining the role of number and size of particles.
- “A” is significantly better than “B”
Objective image quality analysis has advanced significantly in recent years; the challenge is that the technology is not readily available to most practicing imaging professionals.

Our goal is simply to bridge this gap by developing a reliable image analysis tool for everyday use by everybody.

This presentation summarizes our design approach and the hardware and software solutions of a second generation portable image analysis system.
• The new tool provides a broad range of IQ analysis functions, and addresses the requirements of portability, flexibility, upgradeability, affordability, and most importantly, ease-of-use.

• We also place much emphasis on issues of calibration, reliability, and adaptation of international and industry standards.

• We hope our effort has made a contribution to the imaging industry, and towards the theme of “Expansion of Imaging” in ICJ2007.