Estimation of dot area coverage

**Assumption**

- No inter-channel interactions so that the cyan area coverage depends on only the cyan digital count

\[ R_{C_i}(\lambda)^{1/n} = (1 - c_j)P_p(\lambda)^{1/n} + c_j P_c(\lambda)^{1/n} \]

- The least-square estimate minimizes the error

\[ E = \sum_{\lambda \in V} \left[ R(\lambda)c_j^{1/n} - ((1 - c_j)P_p(\lambda)^{1/n} + c_j P_c(\lambda)^{1/n}) \right]^2 \]

- Optimal coverage area

\[ c_j^{\text{opt}} = \frac{\sum_{\lambda} (P_p(\lambda)^{1/n} - R(\lambda_{c_j})(P_p(\lambda)^{1/n} - P_c(\lambda)^{1/n}))}{\sum_{\lambda} (P_p(\lambda)^{1/n} - P_c(\lambda)^{1/n})^2} \]
Fig. 1. Optimized magenta dot area function
Partitioning the three-dimensional cmy space into a grid of eight rectangular cells, formed by nodes at 0, 50, 100 %

As the number of cells increases, the model accuracy improves significantly. At the same time, the dependence on the YN factor decrease.
Spectral regression of the Negebauer primaries

- Treating the primaries spectrum as free variables that can be optimized via regression on a training set of spectral reflectance

\[
\hat{R}(\lambda) = W \cdot P(\lambda) \quad \text{variable}
\]

\[
P_{\text{opt}}(\lambda) = \arg\min_P(E) = \arg\min_P[\|R(\lambda) - W \cdot P(\lambda)\|^2]
\]

\[
P_{\text{opt}}(\lambda) = W^{-} \cdot R(\lambda)
\]
Selection the resolution of the cellular Neugebauer
  - Three levels per colorant offers an acceptable trade-off between accuracy and number of samples

Selection the resolution of C,M,Y stepwedges to generate dot area functions
  - Minimum of 16 samples per colorant is adequate

Selection an additional set of CMY mixture to test the model
  - CMY combinations that does not coincide with the Neugebauer primaries

Evaluation of the accuracy
  - Computing the $\Delta E$

Optimizing the mode with respect to n in some nominal range($1< n < 7$)

Selecting the mixing model depending on the type of halftone screen
Accuracy of the various Neugebauer models

- YN parameter offers significant benefit to the model
- Cellular framework with 625 primaries offers the best accuracy

<table>
<thead>
<tr>
<th>Model</th>
<th>No. of Spectral Measurements</th>
<th>Avg. $\Delta E_{ab}^*$</th>
<th>95% $\Delta E_{ab}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic spectral</td>
<td>72</td>
<td>8.88</td>
<td>16.3</td>
</tr>
<tr>
<td>Yule–Nielsen corrected</td>
<td>72</td>
<td>3.50</td>
<td>7.80</td>
</tr>
<tr>
<td>Cellular, 3$^4$ primaries, Yule–Nielsen corrected</td>
<td>137</td>
<td>2.96</td>
<td>6.0</td>
</tr>
<tr>
<td>Cellular, 5$^4$ primaries, Yule–Nielsen corrected</td>
<td>681</td>
<td>2.01</td>
<td>5.0</td>
</tr>
<tr>
<td>Yule–Nielsen corrected, global spectral regression</td>
<td>188</td>
<td>2.27</td>
<td>5.3</td>
</tr>
</tbody>
</table>
Empirical techniques for forward characterization

- Lattice-based techniques
  - Generate a regular grid of training samples in m-dimensional device space, print and measure these samples, and use a lattice-based technique to interpolate among the measured colorimetric values

- Simple to determine a suitable grid size for a CMY printer
  - Generate uniformly spaced lattices of size $s^3 (5 \leq s \leq 10)$ and generate test target of CMY sample
  - Measuring the CIELAB values for both the lattice and the test data
  - Selecting a three-dimensional interpolation technique and compute $\Delta E$ between estimated and measured CIELAB
  - Logical choice for lattice size is the smallest $s$ for which an increase in lattice size does not yield
There is no appreciable gain in increasing the grid size beyond $s=8$
Sequential interpolation (SI)

- Sequential interpolation
  - Decompose the CMYK space into a family of CMY subspace at different K and corresponding CIELAB gamuts
  - Note that as K increase, the variation in color and gamut volume decrease

1. Project the input CMYK point onto the K dimension and select neighboring levels $K_j$ and $K_{j+1}$

2. Project the input CMYK point onto CMY space and Perform three dimensional interpolation on the two CMY Lattice corresponding to level $K_j$ and $K_{j+1}$ to produce Two CIELAB points

3. Use the input K value to perform one-dimensional Interpolation of these two CIELAB points
For approximately the same lattice
  ▪ SI technique offers superior accuracy

<table>
<thead>
<tr>
<th>Model</th>
<th>CIE '94 ΔE</th>
<th>Number of LUT Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular 4 × 4 × 4 × 4 lattice</td>
<td>3.0</td>
<td>256</td>
</tr>
<tr>
<td>Sequential interpolation with 5³, 4³, 3³, 2³ CMY lattices corresponding to k = 0, 85, 170, 255</td>
<td>1.8</td>
<td>224</td>
</tr>
</tbody>
</table>

Other empirical approach
  ▪ Neural network, analytic model …