A Regression-Based Model of Colorimetric Tone Reproduction for Use in Print Standards

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Main Topics

- The **Problem**
- Our **Solution**
- Some **Applications**

The Problem

- Create a math model for the colorimetric response of a colored ink ramp.

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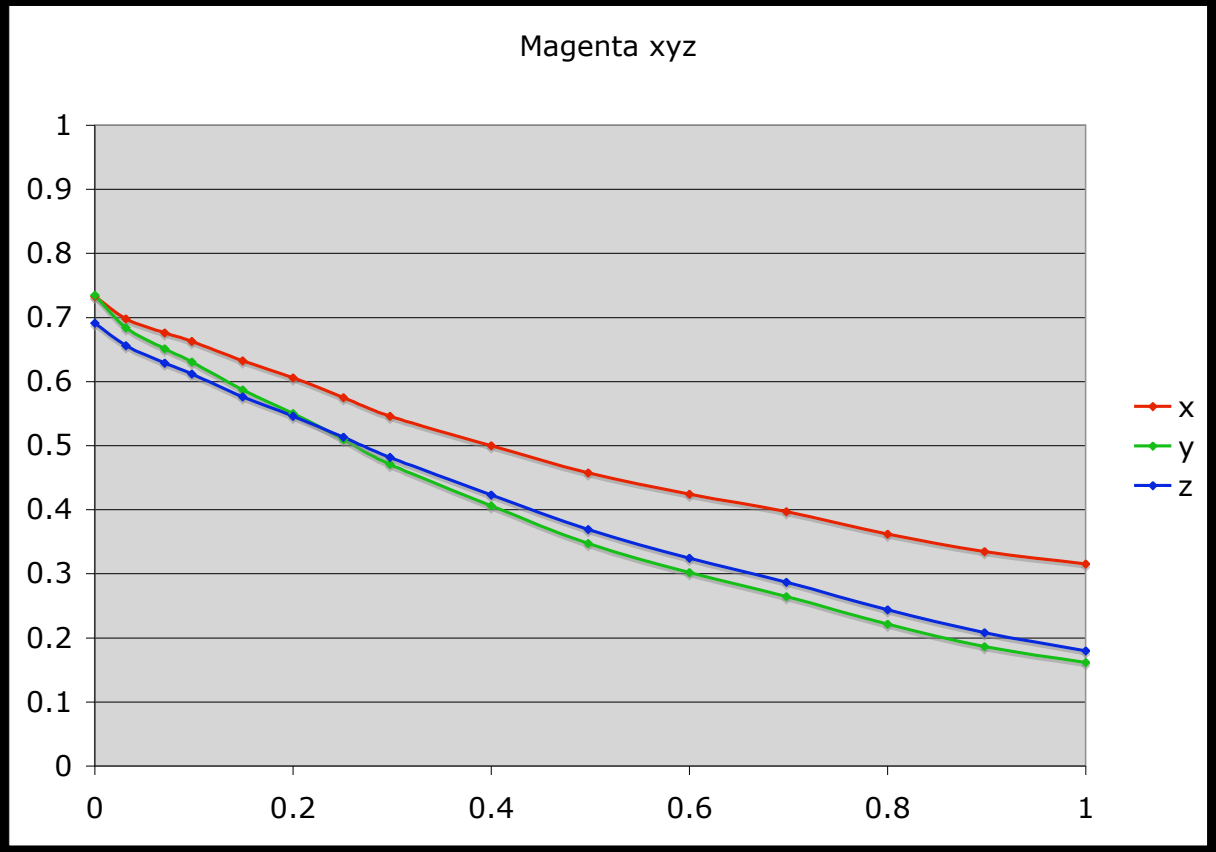


Design Goals

- Appropriate
  - Capture Essential Qualities
  - Filter Unwanted “Noise”
  - Model “Ideal” Behavior
  - Wide Applications

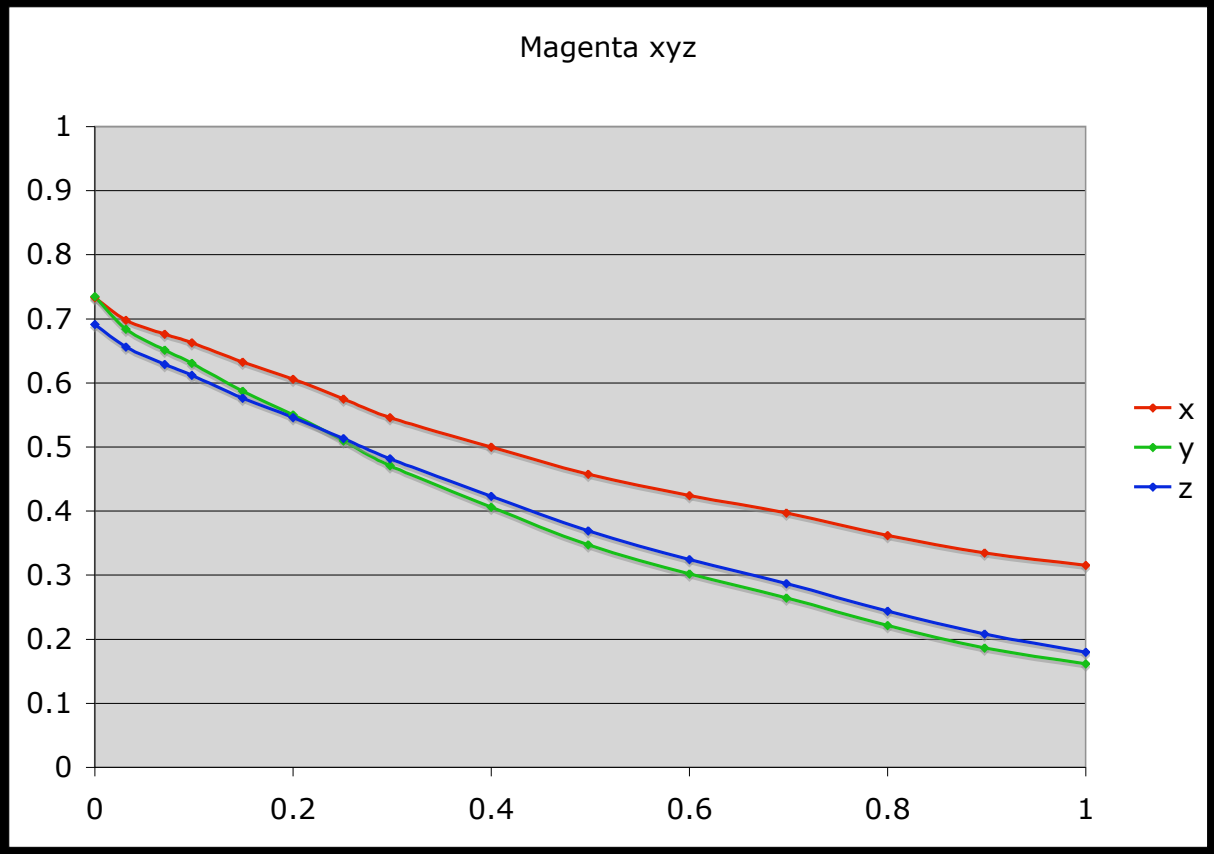
Design Goals

- Easy to Understand
  - Familiar
  - Intuitive
  - Graphic
- Easy to Use
  - Simple Math
  - Regression Method

Ink Ramps

- Single-ink ramps

Ink Ramps



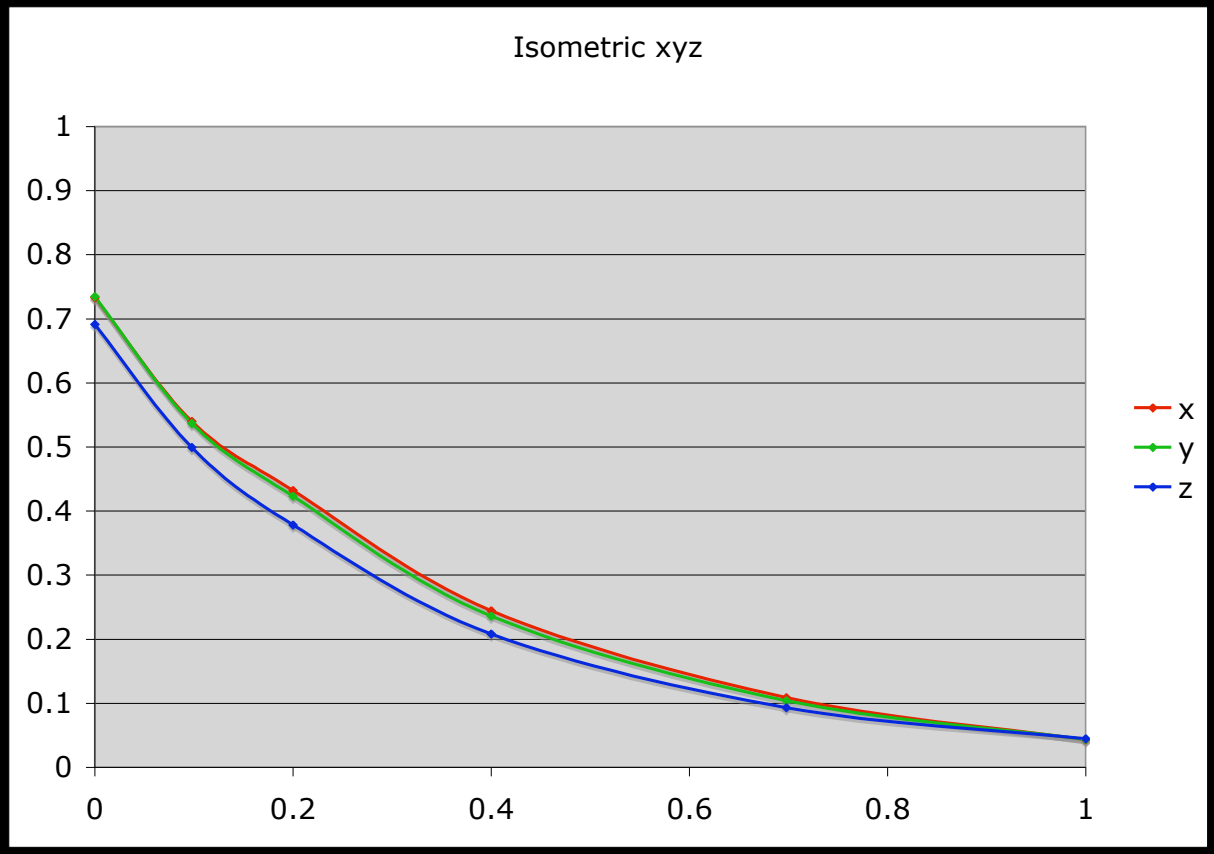
Ink Ramps

- Single-ink ramps
- Multi-ink ramps

Ink Ramps

- Single-ink ramps
- Multi-ink ramps
- Isometric ramp (C=M=Y)

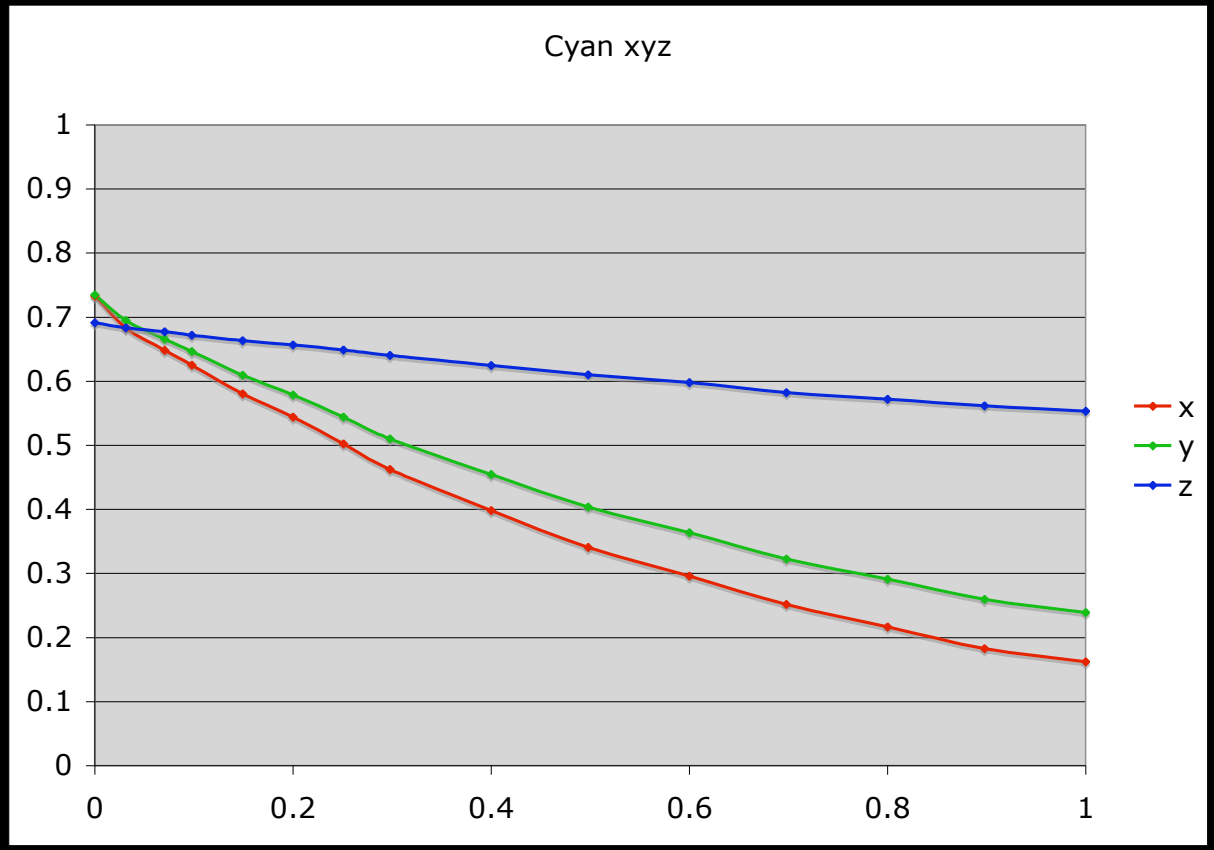
Ink Ramps



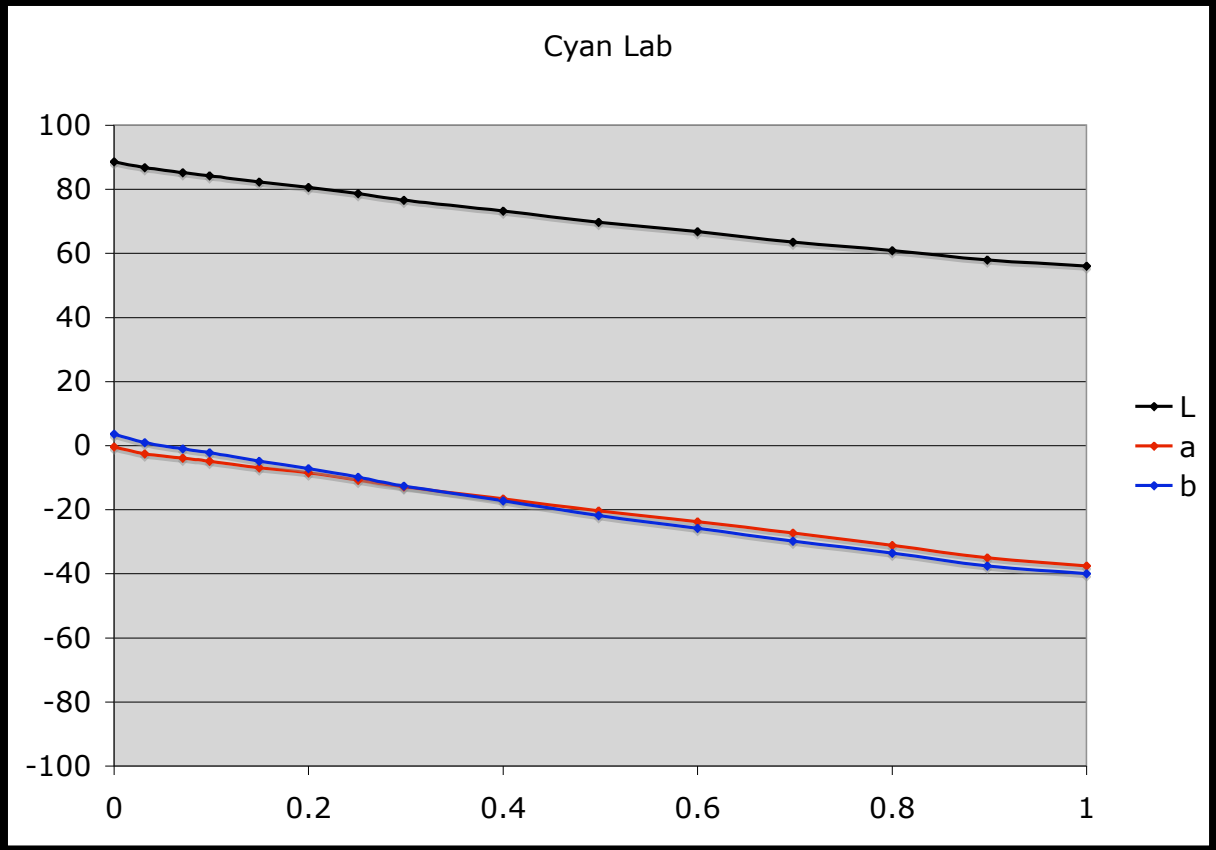
Colorimetric Measurements

- We use colorimetry instead of densitometry
- xyz (tristimulus values) are fundamental measurements

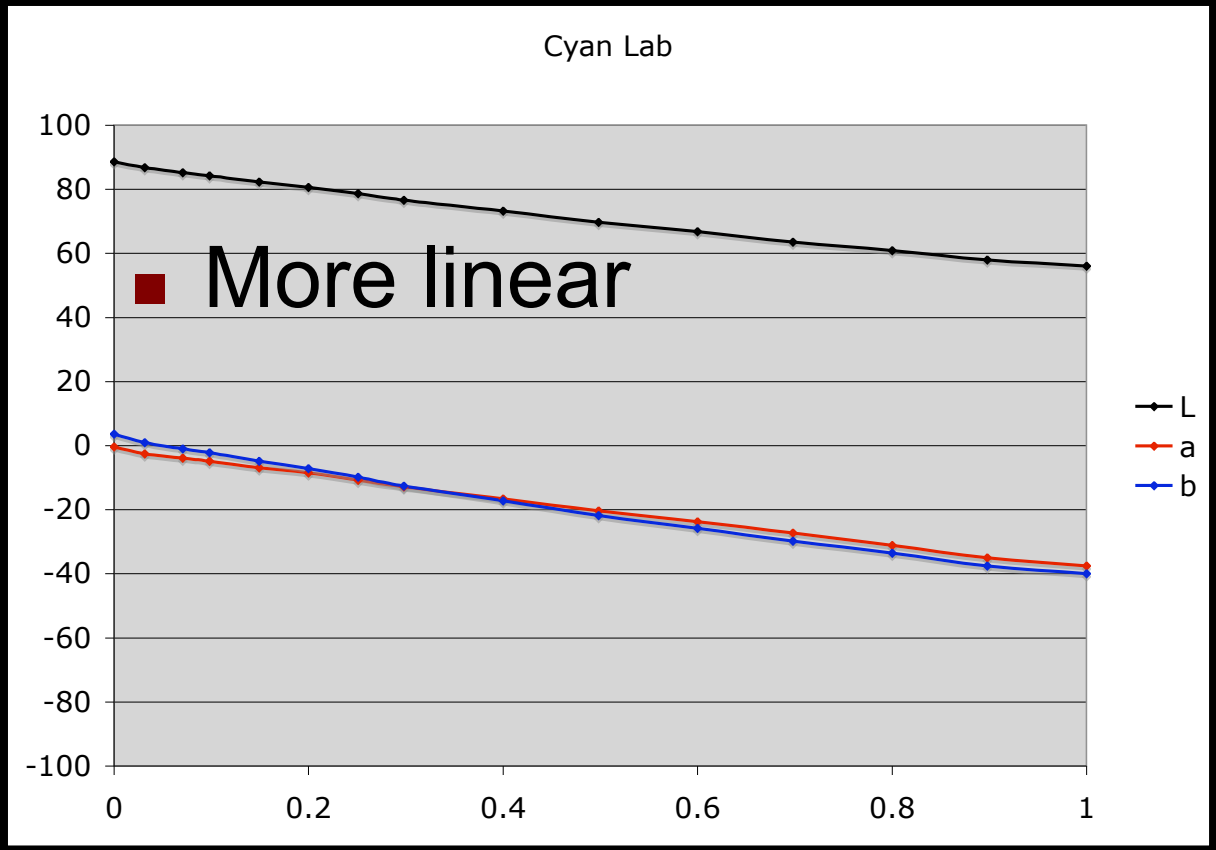
Colorimetric Measurements



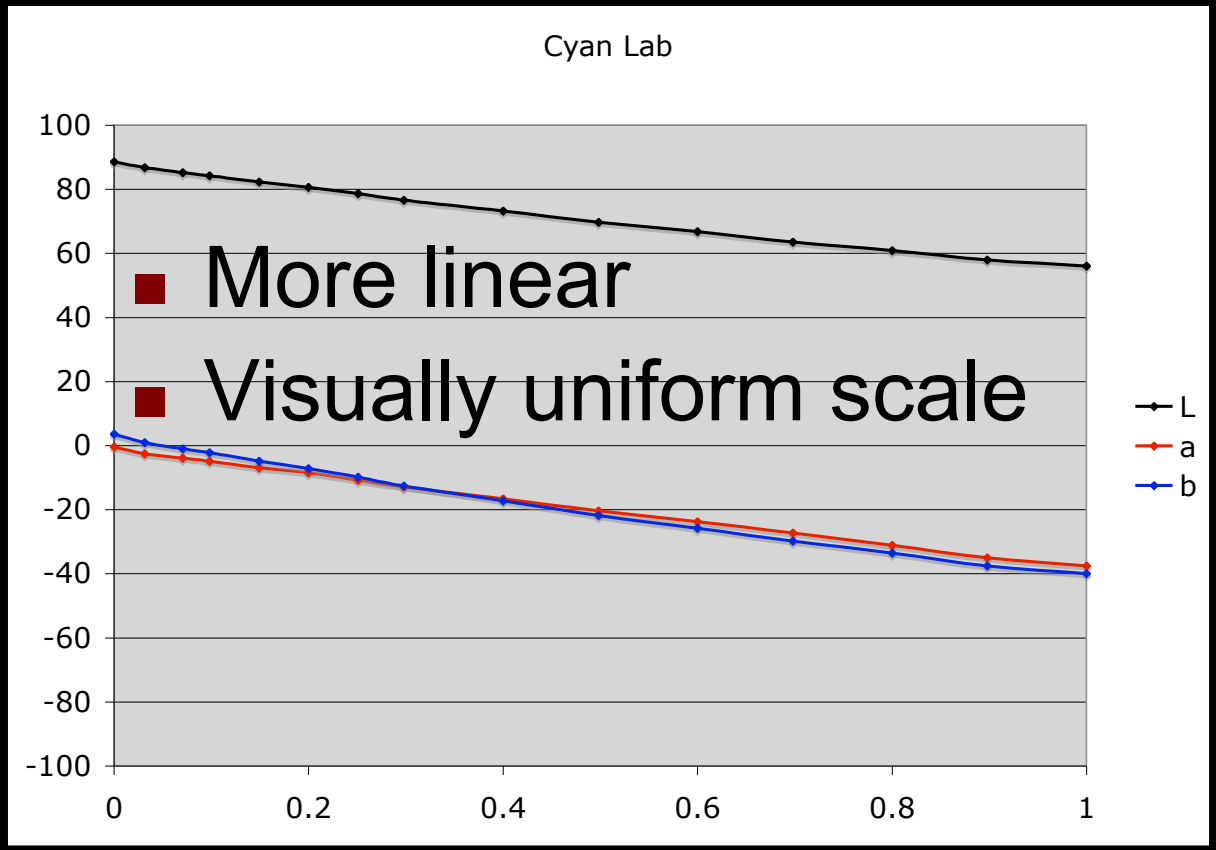
Lab Measurements



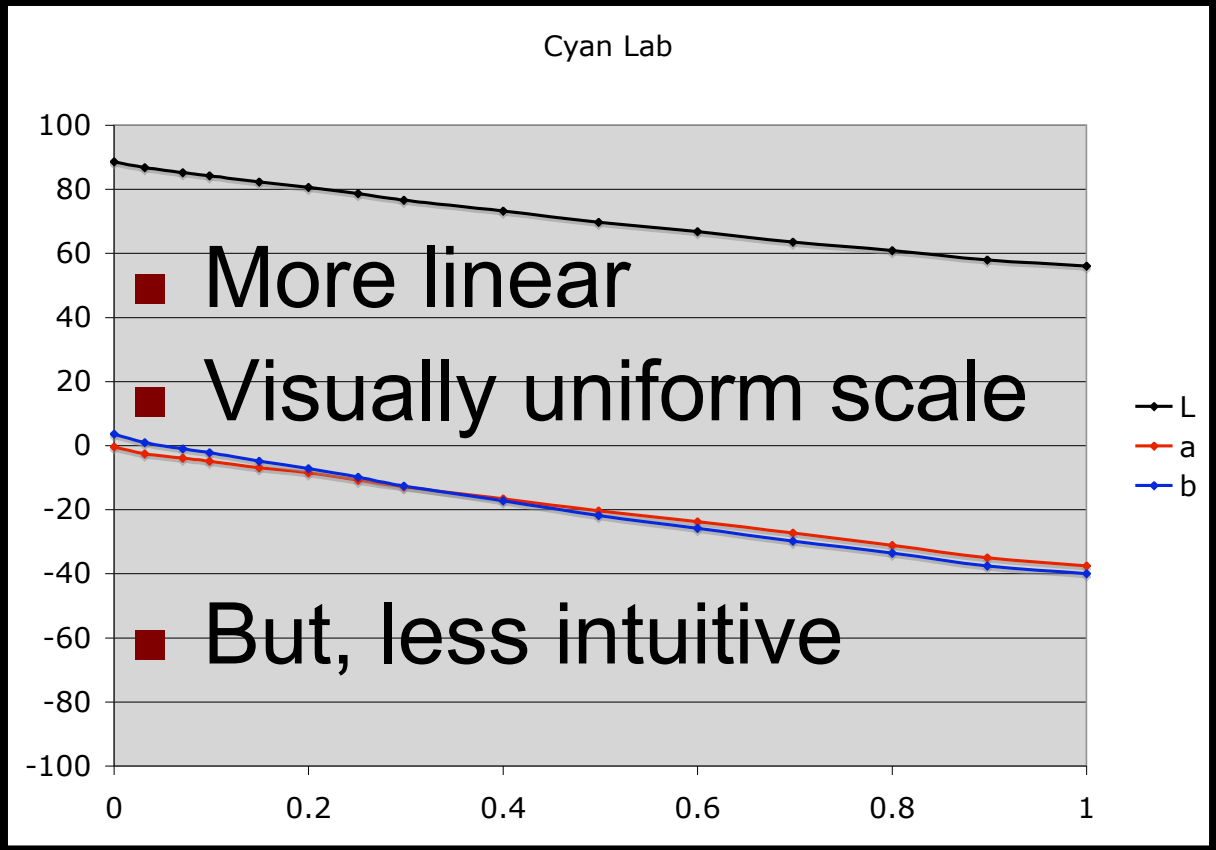
Lab Measurements



Lab Measurements



Lab Measurements



$L_xL_yL_z$ Measurements

- xyz is intuitive but not linear

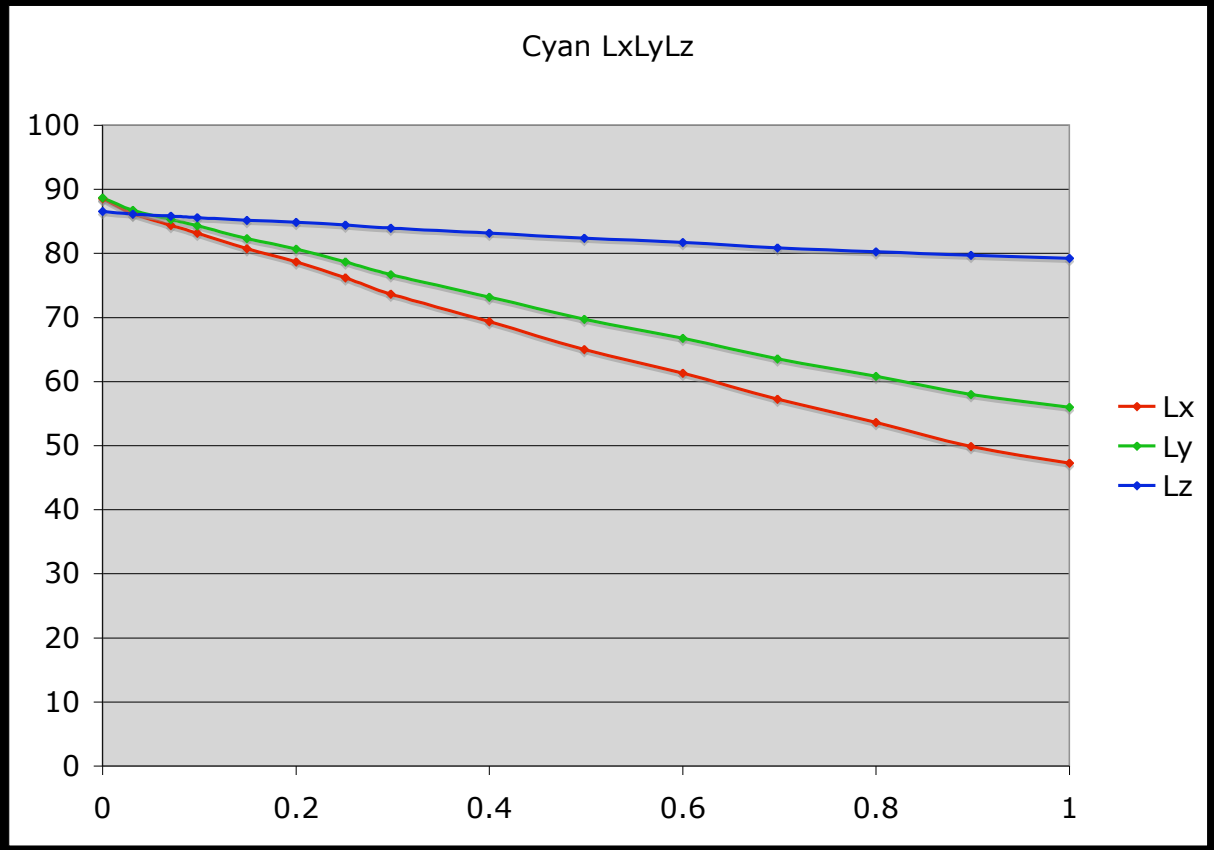
$L_xL_yL_z$ Measurements

- xyz is intuitive but not linear
- Lab is linear but not intuitive

$L_xL_yL_z$ Measurements

- xyz is intuitive but not linear
- Lab is linear but not intuitive
- Solution: transform x and z in the same way that y is transformed to L
- We call this $L_xL_yL_z$

$L_xL_yL_z$ Measurements



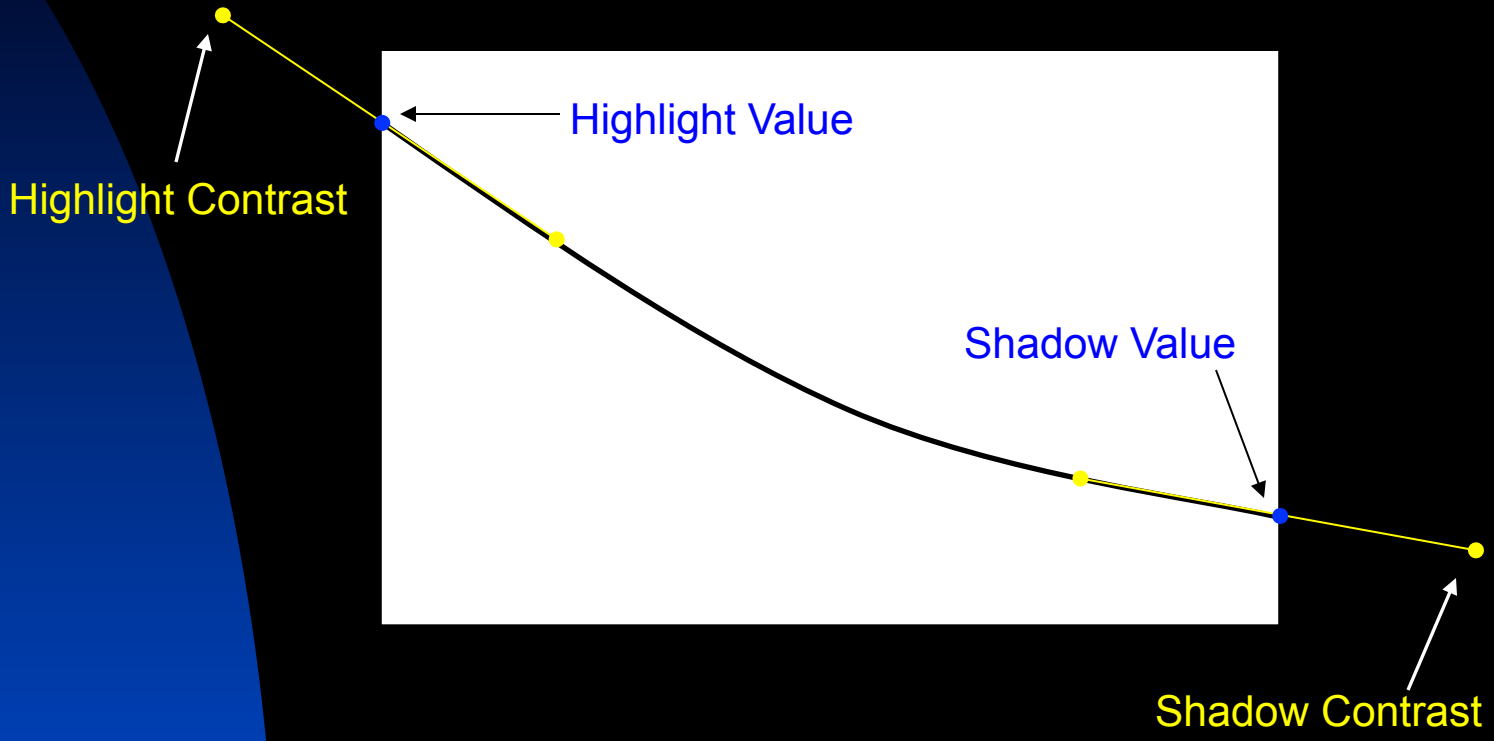
Modeling $L_x L_y L_z$

- Any model is a tradeoff
- We chose the **Hermite spline**
  - Simple
  - Accurate
  - Easy to use
  - Intuitive

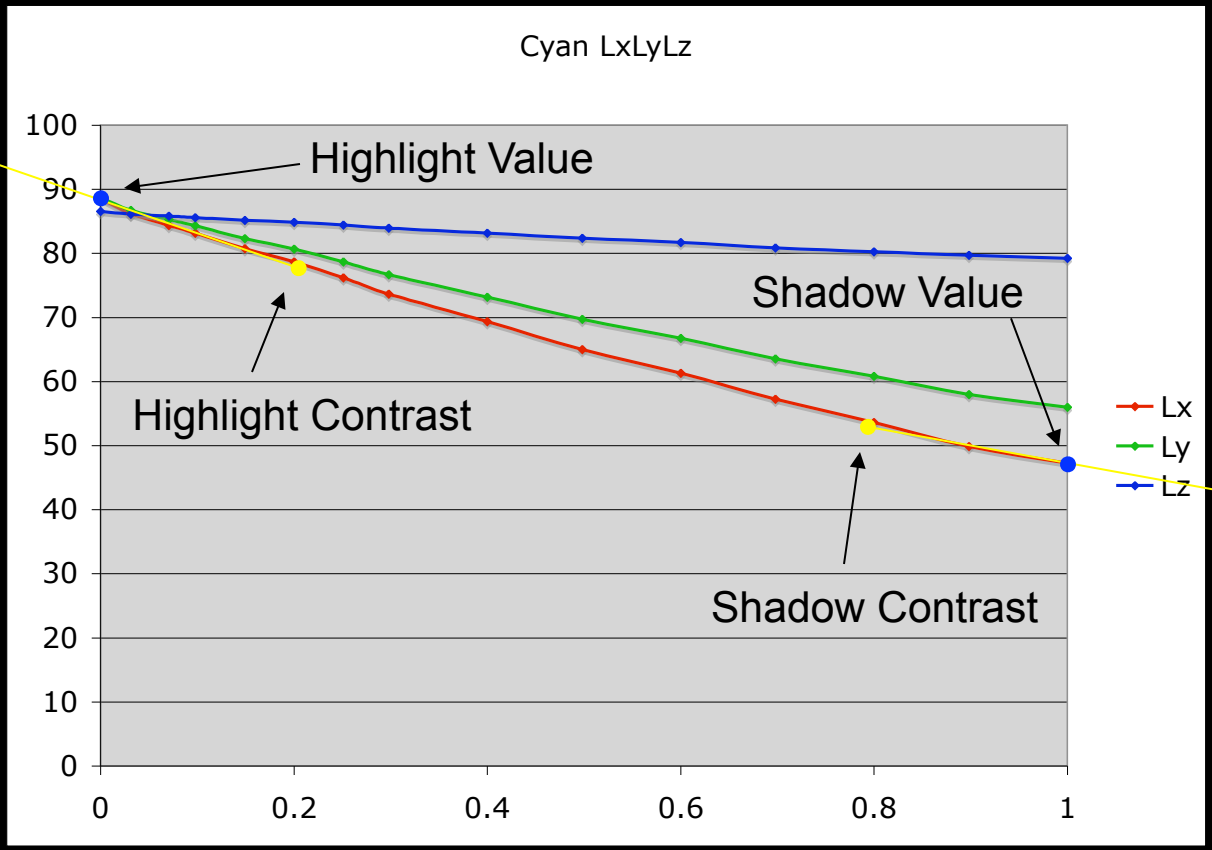
Hermite Spline

- A form of cubic polynomial with just four parameters:
  - Highlight value
  - Shadow value
  - Highlight contrast
  - Shadow contrast

Hermite Spline

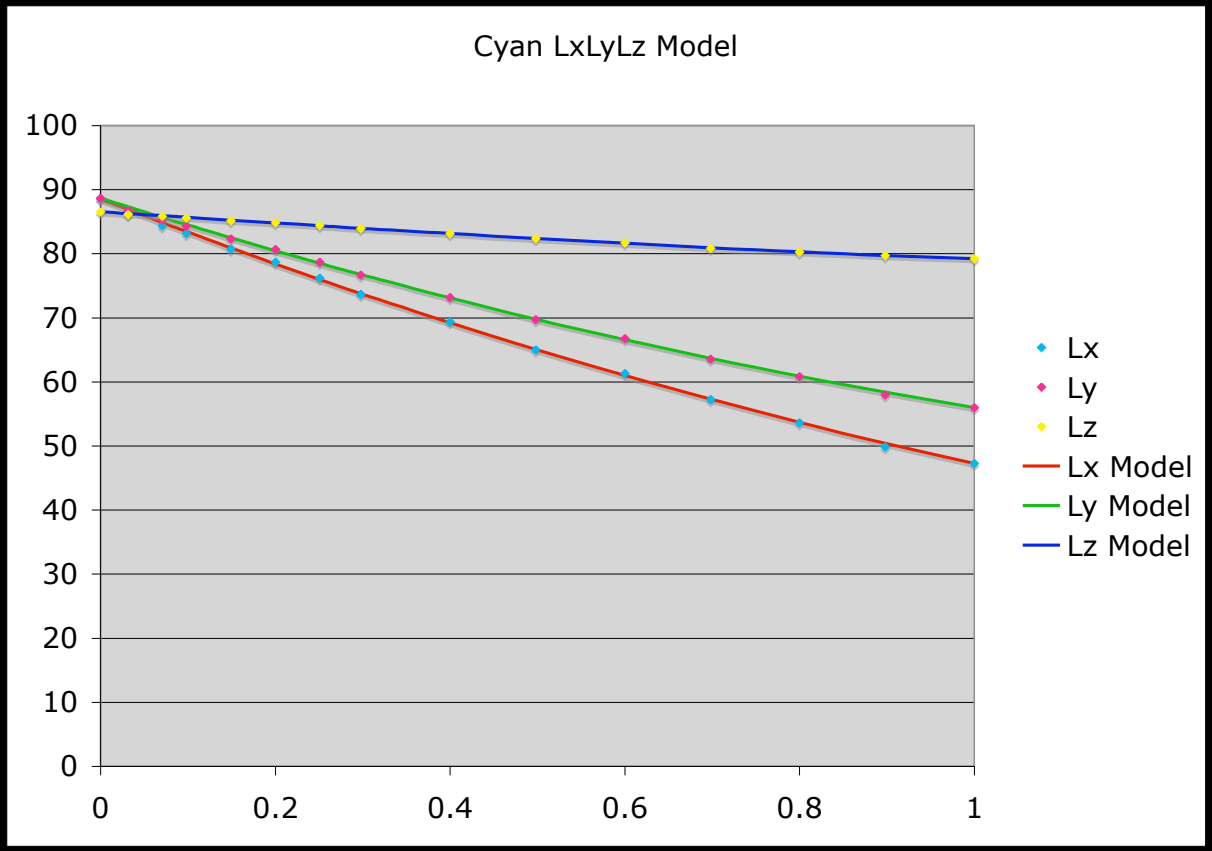


Hermite Spline



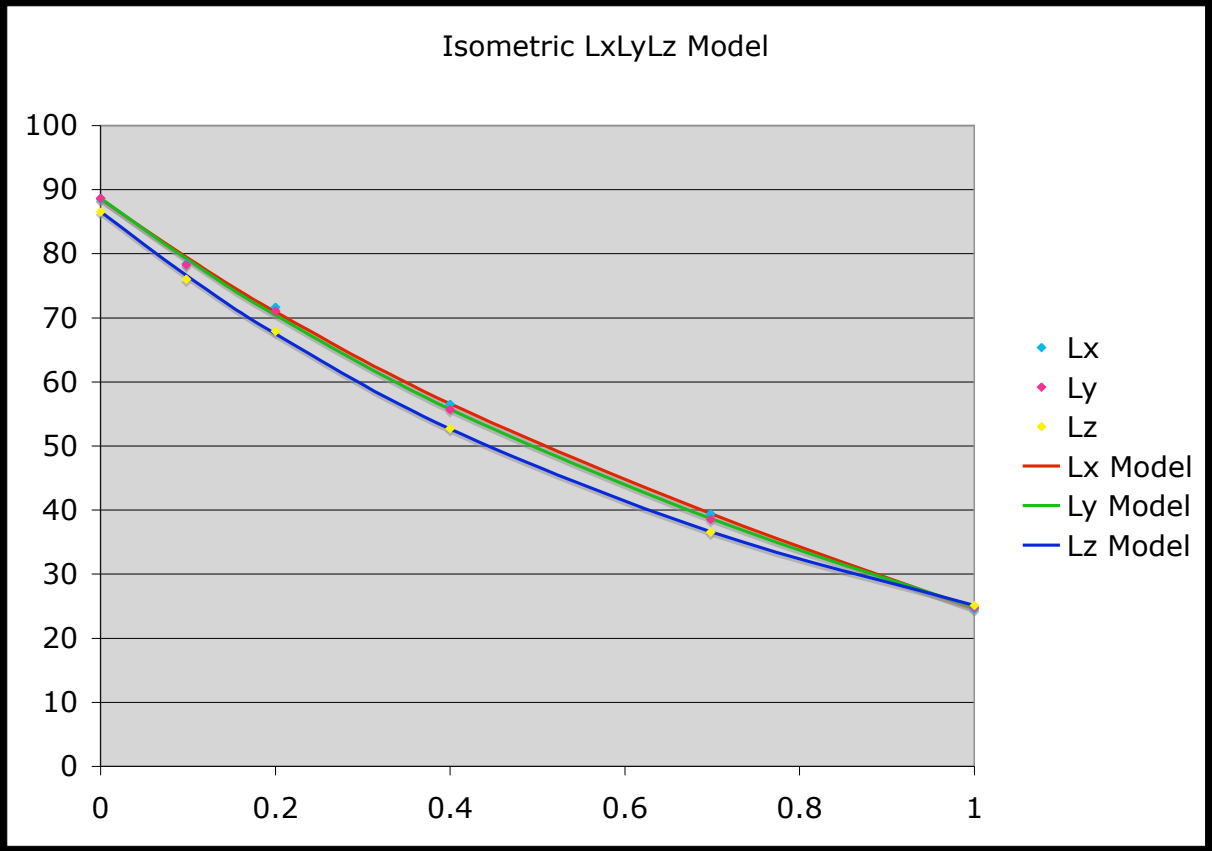
Highlight Value	Shadow Value	Highlight Contrast	Shadow Contrast
88.59	47.30	-53.36	-29.73

Complete Model



	Highlight Value	Shadow Value	Highlight Contrast	Shadow Contrast
Lx	88.59	47.30	-53.36	-29.73
Ly	88.67	56.02	-43.09	-22.13
Lz	86.56	79.22	-8.92	-4.75

Complete Model



	Highlight Value	Shadow Value	Highlight Contrast	Shadow Contrast
Lx	88.59	24.55	-97.85	-48.62
Ly	88.67	24.83	-101.40	-43.04
Lz	86.56	25.14	-107.15	-33.15

Regression Method

- Fits model to measured data
- Highlight and shadow values are measured
- Highlight and shadow contrasts are computed for best fit
- Converges fast and reliably

Testing & Validation

- Collection of data sets
  - Sheetfed offset
  - Web offset
  - Newspaper
  - Gravure
  - Halftone proofs

Testing & Validation

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- Determined average and maximum ΔE for five ramps

Testing & Validation

- Collection of data sets

Data Set	Black		Cyan		Magenta		Yellow		Isometric	
	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE
ANSI CGATS TR001	0.37	1.25	0.43	1.25	0.53	1.41	0.64	1.37	0.46	1.14
ANSI CGATS DTR004	0.61	1.93	0.55	1.31	1.04	1.98	0.94	2.03	0.71	1.49
FOGRA27 (Coated #1)	0.13	0.38	0.21	0.50	0.44	1.01	0.35	0.82	0.31	0.63
FOGRA29 (Uncoated #4)	0.14	0.34	0.08	0.19	0.19	0.45	0.23	0.55	0.06	0.10
IFRA26 (Newsprint)	0.11	0.33	0.08	0.19	0.11	0.28	0.11	0.27	0.12	0.24
ECI Gravure (Matte)	0.15	0.36	0.22	0.40	0.29	0.54	0.21	0.44	0.60	0.96
Web Publication (Linear)	0.47	1.65	0.33	0.91	0.43	1.39	0.78	2.30	0.65	1.74
Sheetfed Coated (Linear)	0.29	0.96	0.37	1.27	0.48	1.75	0.67	1.89	0.61	1.25
Sheetfed Coated (FM)	0.63	1.70	0.37	1.36	0.60	2.10	0.68	1.42	0.77	1.40
Approval SWOP Recipe	0.42	1.03	0.33	0.66	0.43	0.84	0.40	0.99	0.44	0.84
Final Proof	0.31	0.81	0.20	0.38	0.23	0.62	0.24	0.67	0.19	0.42
Digital Matchprint	0.29	0.76	0.53	1.30	0.49	1.93	0.54	1.87	0.77	1.78

- Determined average and maximum ΔE for five ramps

Application to Print Standards

- **Replace paper/SID/TVI specs** for process color ramps
- Replace gray balance specs with isometric ramp
- Standard is completely defined using colorimetry
- Tone curves are smooth, formula-based

Application to Color Matching

- Compute TRCs to calibrate platemaking
- Compute device links to match proofs to presswork
- Compute device links to normalize incoming files

Thank You!

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Extra Slides

- Derived Measures
- Future Work
- Regression Method Flowchart

Derived Measures

- Bow is the location of the model's midpoint relative to a straight-line function. Similar to midtone TVI.
- Twist is the contrast of the model's midpoint relative to a straight-line function. Similar to midtone contrast.

Future Work

- Single-value tone measure for use in the pressroom. We call this colorimetric tone value (CTV).
- Gray balance measures based on isometric ramp.

Regression Flowchart