Colorimetric Measurements in the Pressroom

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Our Mission

- Develop measures that describe the visual appearance of printing
- Promote engineered appearance as a component of print standards
- Work for the adoption of standards
- Help printers and print buyers improve their processes through standards

Our Mission

- Develop tools for diagnosing pressroom problems
- Develop tools for calibrating presswork
- Develop tools for color matching
- Bring colorimetry into the pressroom

Background

- Calibrate an Approval - but to what?
- Existing print standards didn't help
- Had some ideas on improving print standards
- Did experiments matching presswork to proofs using isometric ramp
- Technical paper presented at 2004 TAGA annual meeting

Background

- Continued work on measurement of print using colorimetry
- Developed new ideas on modeling colorimetric tone curves
- Second technical paper presented at 2005 TAGA annual meeting

Background

- Software tools developed for research had commercial application
- Doppelganger founded to pursue commercial opportunities
- Looking for consulting partnerships

Conventional Pressroom Measurements

- Density is useful for process control
- Colorimetry is required for color and appearance measurements
- Manual instruments limit the scope of practical measurements
- Instruments developed for color management (e.g. ICColor) overcome these limitations

Colorimetric Pressroom Measurements

- Now, it's very easy to gather lots of data from a press sheet
- But, what data should we look at?
- And once we have that data, how do we interpret it?

Colorimetric Pressroom Measurements

- Print is normally characterized by measuring many patches, e.g. IT8.7/3 or ECI2002
- ICC profiles are made from this data
- Aside from the geometry of color gamuts, ICC profiles don't tell us much about the printing process

Sleuthing with Ink Ramps

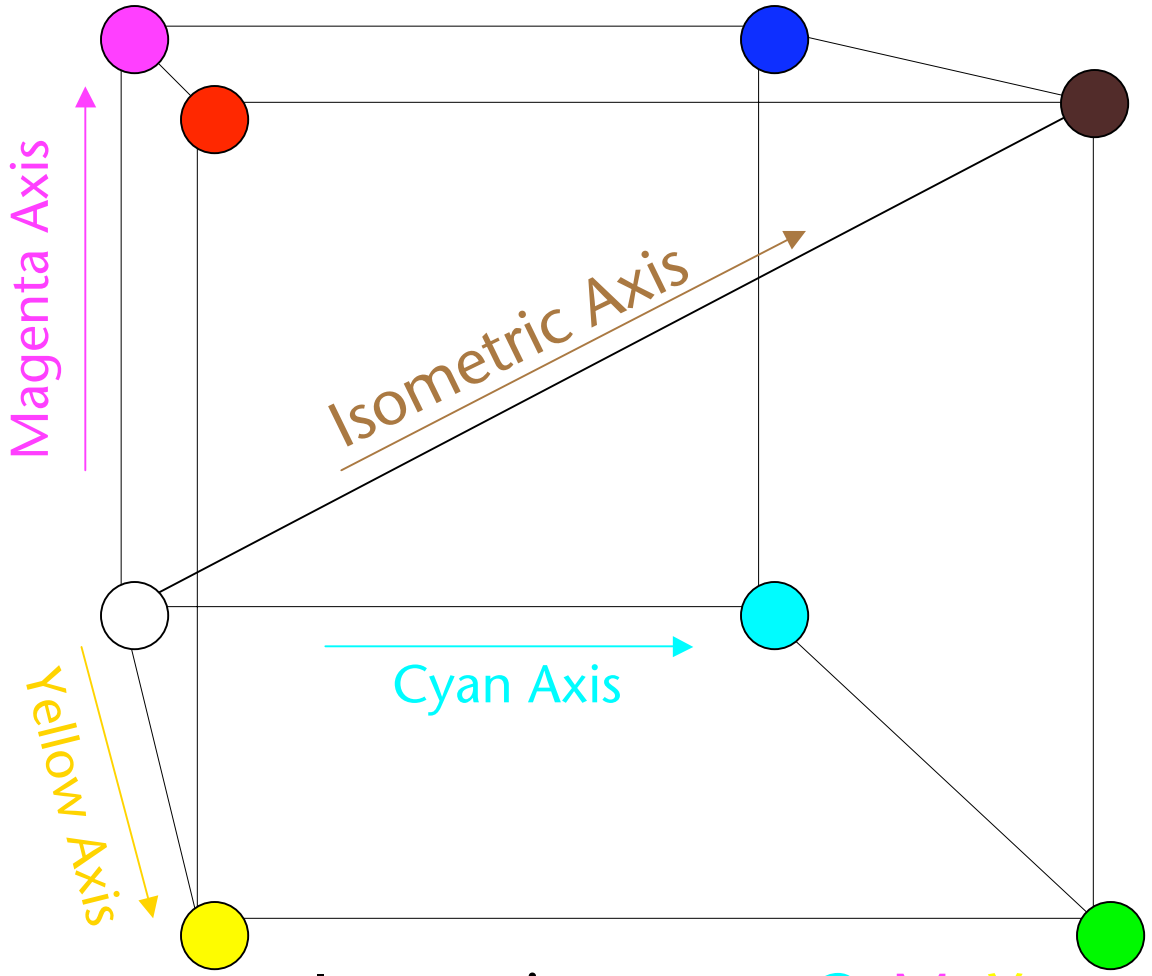
- Well chosen ink ramps can reveal a great deal about the printing process
- Existing test targets are usable, but not ideal
- So, we designed a special test target to get the information we wanted

PressCal6 Test Target

PressCal6 Description

- 18 step CMYK ramps
- 18 step Isometric ramp
- 18 step CMY interpolation ramps
- 7 step CMYK highlight retention ramps
- 5 step M+Y, C+Y, C+M overprint ramps
- 5 step R+C, G+M, B+Y ramps
- 5 x 5 step Isometric + K array
- SWOP, GRACoL and ISO 12647-2 gray balance ramps

CMY Color Space



Isometric means C=M=Y

The Isometric Ramp

- The visual appearance of a printed sheet (or proof) is tightly coupled to the tone reproduction of the isometric ramp
- This is actually very old knowledge dressed up in new clothes
- Color separation cameramen knew this in the 1940s
- The RIT TRAND chart was built upon this concept

The Isometric Ramp

- Why measure the isometric ramp, rather than a gray ramp?
- We don’t know what combinations of CMY will print gray
- Color matching is easier and more accurate using actual measured data
- Results are virtually identical
- Isometric data is contained in every device characterization target

Measuring the Target

- Target is measured with an ICColor or Spectrolino/SpectroScan
- Spectral data is saved in CGATS.17 format (tab-delimited ASCII)
- For presswork, it is essential to measure several sheets and average the data
- Note that ink film may vary considerably in the direction of paper feed, so it's a good idea to print two targets side-by-side, rotated 180 degrees

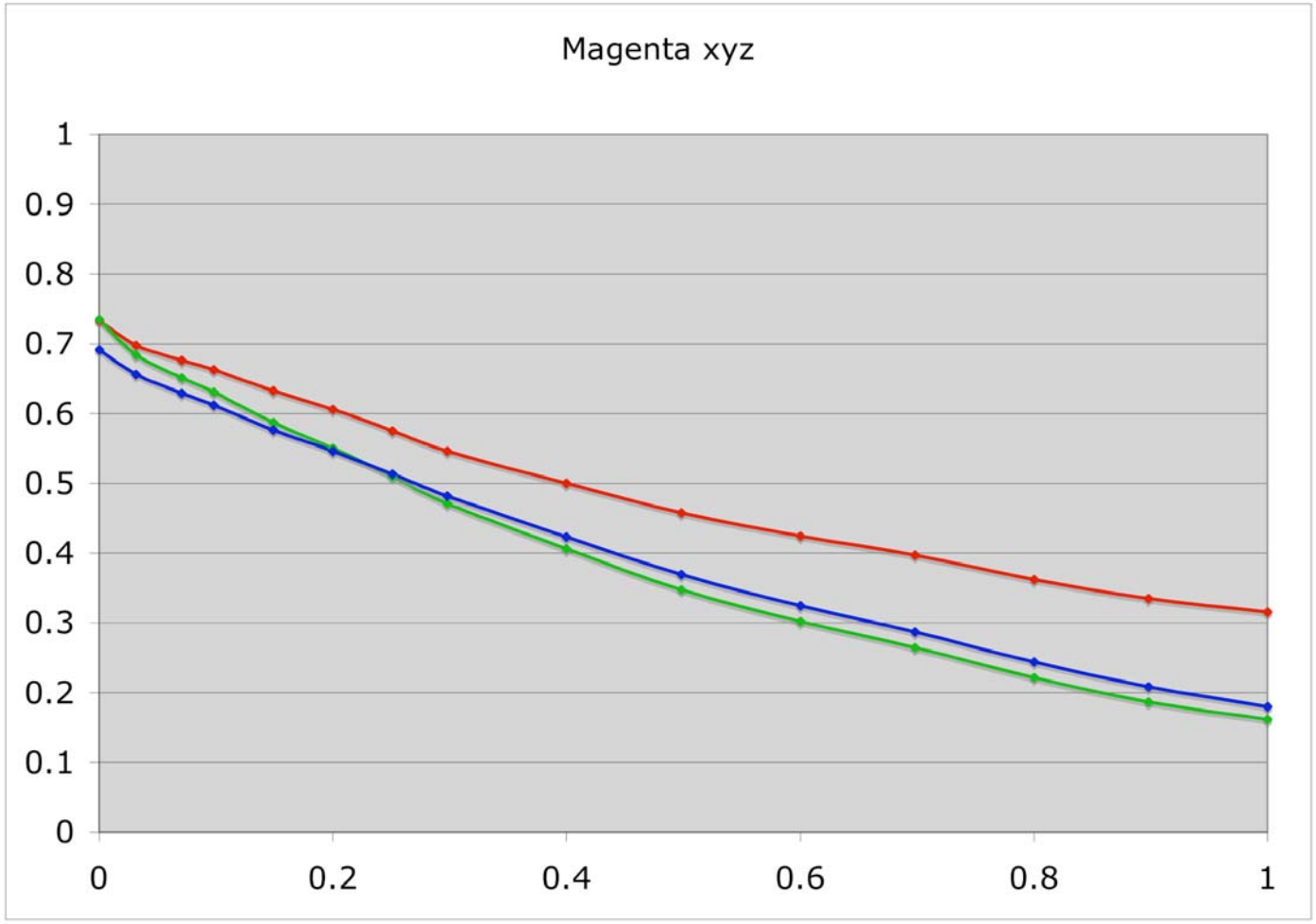
ReportWriter Software

- Processes measurement data from PressCal test target into a detailed print analysis report
- Provides conventional density-based measures and colorimetric measures
- Compares the test print to a reference
- Also works with IT8.7/3 and ECI2002 test targets

Analyzing the Data

- Spectral data is converted to both density and colorimetry
- Colorimetric measurements (XYZ) are computed per CGATS.5-2003
- These values are divided by white-point values to get normalized (xyz) values
- When xyz values are plotted against CMYK, the results are similar to Murray-Davies %-dot

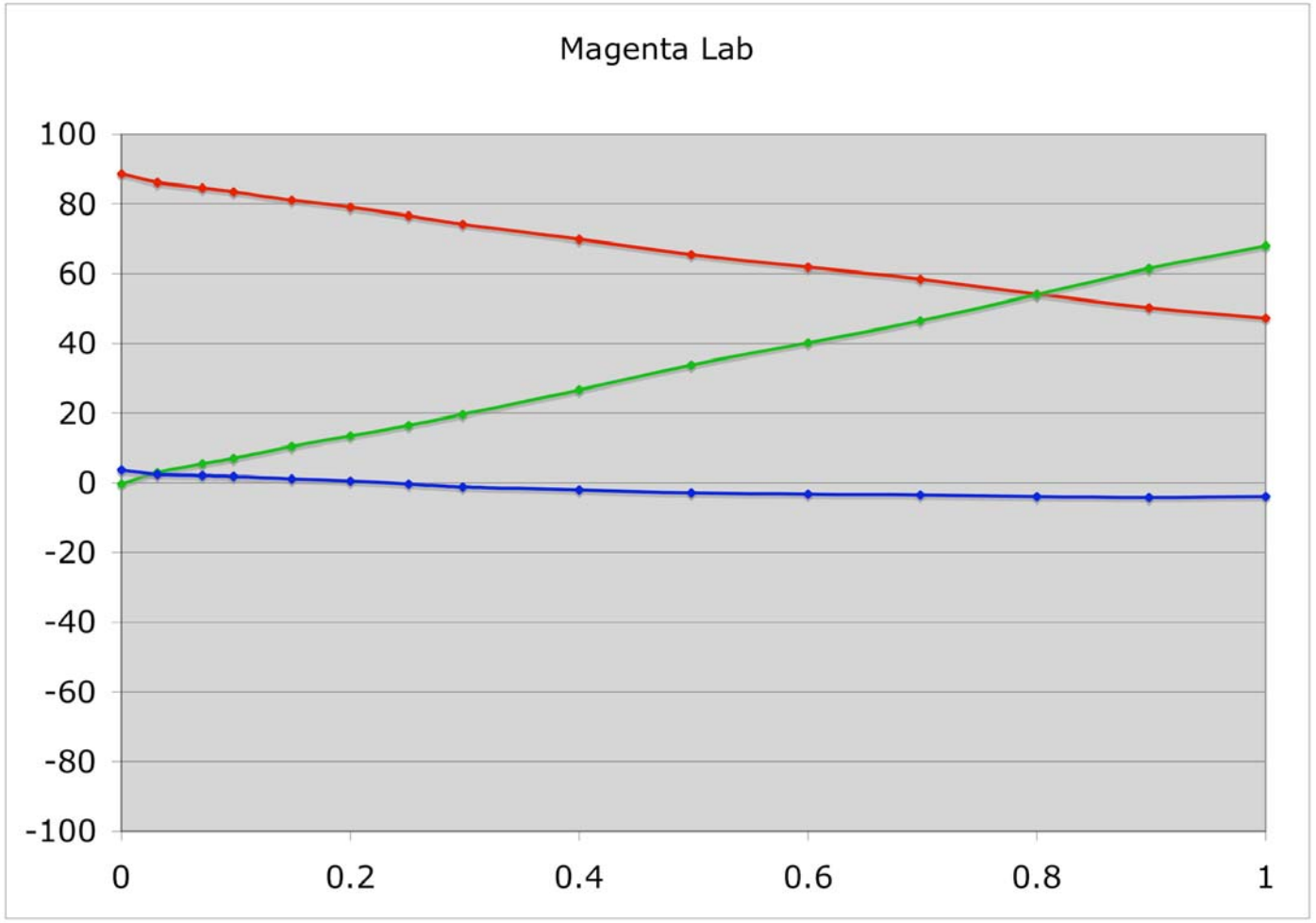
TR 001 xyz vs. %-dot



Advantages of Lab

- Curves plotted with xyz data are non-linear, as with M-D %-dot
- If the xyz data is converted to Lab, it becomes more linear
- Lab is a visually uniform color space, which makes it easier to work with
- But, Lab is not symmetrical, which detracts from its use

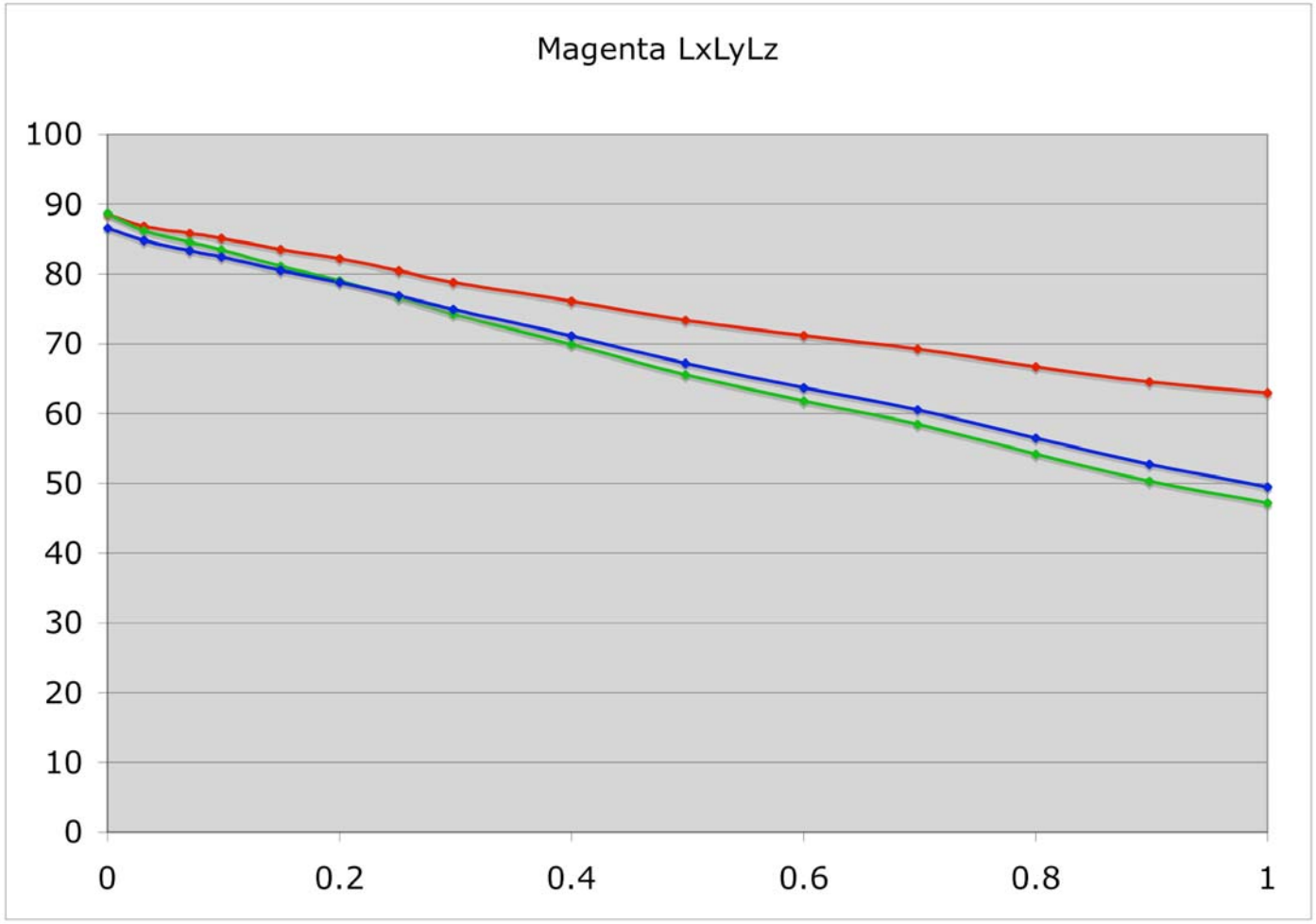
TR 001 Lab vs. %-dot



Improving on Lab

- The problem with Lab is that a and b are based on differences, while L is based only on y (asymmetrical)
- We devised a better solution which is symmetrical, yet retains the desirable properties of Lab.
- We call this color space LxLyLz
- Lx and Lz are computed from x and z in the same way the L is computed from y

TR 001 LxLyLz vs. %-dot



Properties of LxLyLz

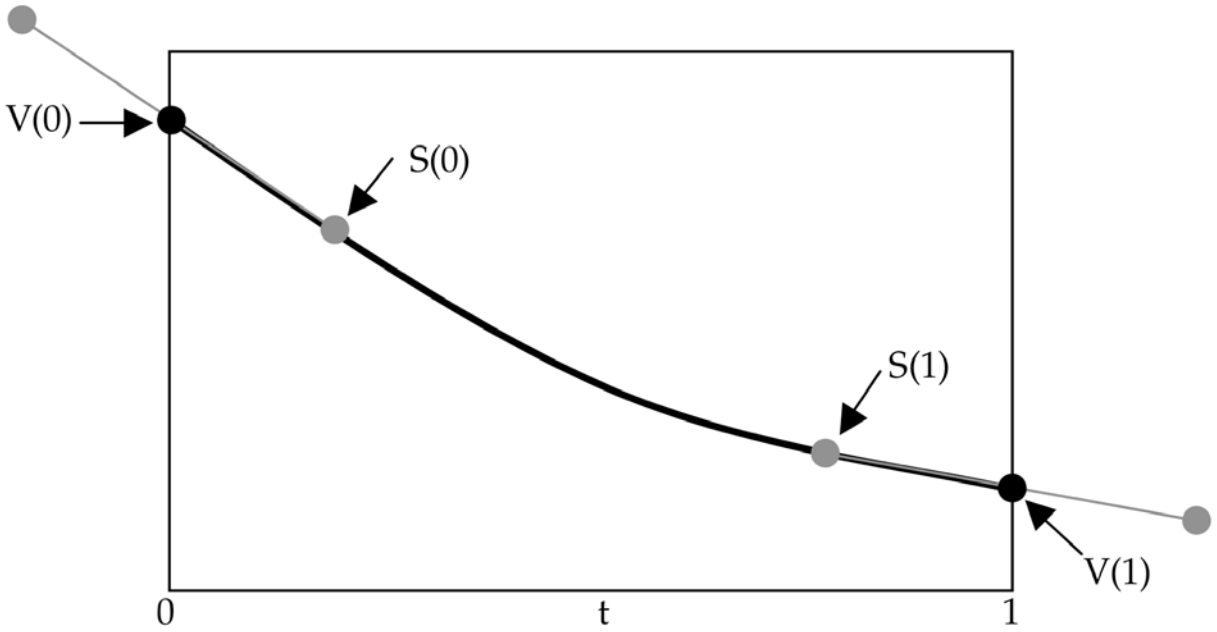
- LxLyLz is symmetrical
- Ly is the same as L in Lab
- Values range from 100 (perfect white) to 0 (perfect black)
- Neutrals have Lx=Ly=Lz
- LxLyLz is visually uniform
- LxLyLz may be easily converted to/from Lab

Modeling the Data

- The LxLyLz curves are nearly straight lines for the CMYK ramps
- It is possible to model these curves using simple mathematical functions
- We tested several possible models against an assortment of real data sets, and found a model that works well
- That model is called the Hermite spline

Hermite Spline

The spline parameters (V0, V1, S0, S1) are easy to visualize, and correspond to the familiar concepts of value and contrast. The slopes at t=0 and t=1 are commonly known as "highlight contrast" and "shadow contrast."

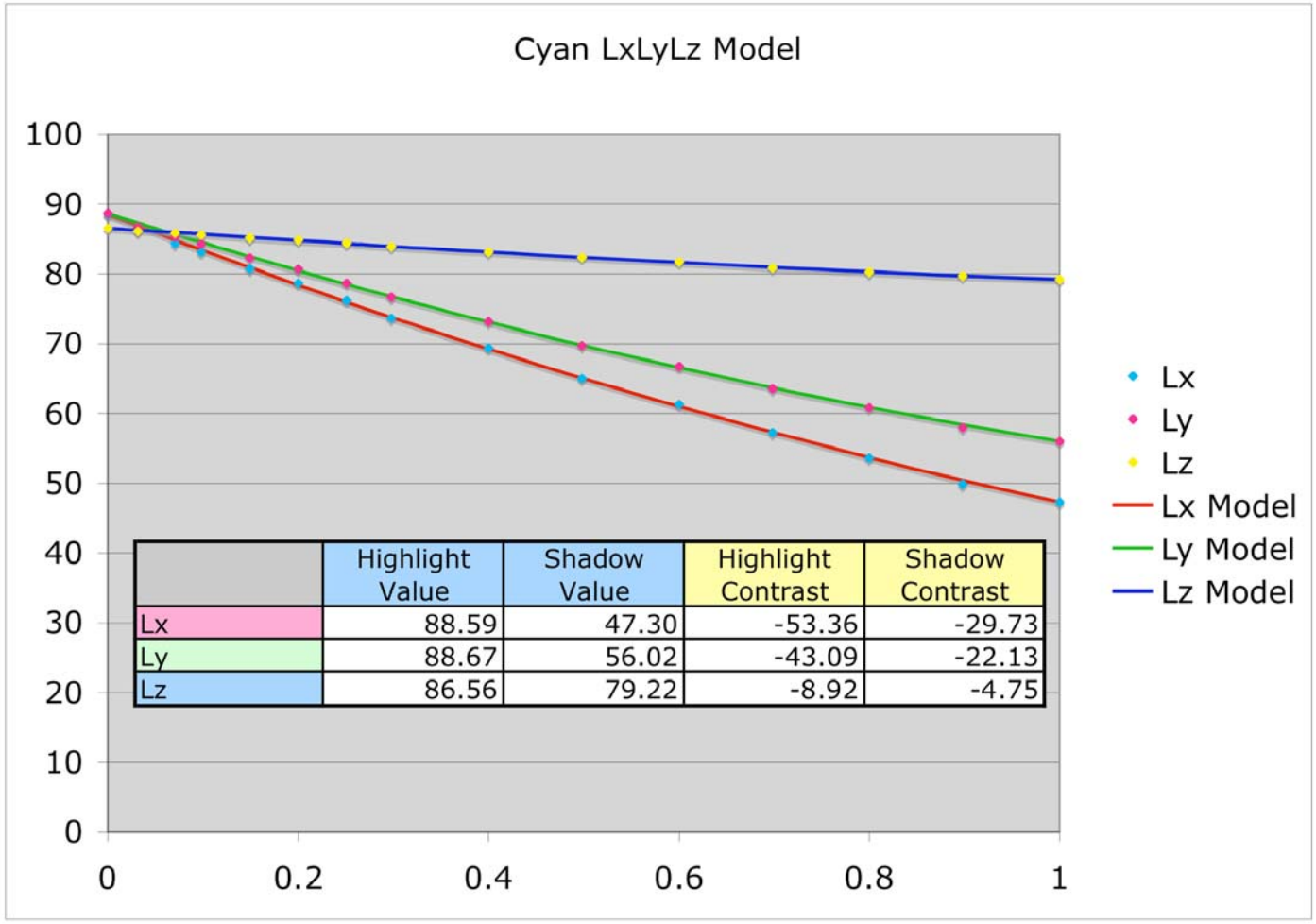


The figure above illustrates the Hermite parameters. V(0) is the value at the left endpoint (t=0), and S(0) is the slope or contrast. V(1) is the value at the right endpoint (t=1), and S(1) is the slope or contrast.

Fitting Curves to the Data

- The Hermite spline is a cubic polynomial expressed in a convenient form
- The spline may be fitted to the actual data using least squares regression
- Each curve has four numeric parameters
- There are three curves (LxLyLz) per ramp
- The spline curve is perfectly smooth

TR 001 LxLyLz Spline 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

How Good is this Model?

- We tested over 200 data sets
  - Sheetfed offset
  - Web offset
  - Gravure
  - Newsprint
  - Prepress proofs
- We computed the average and maximum ΔE for the CMYK and Isometric ramps

Selected Test Results

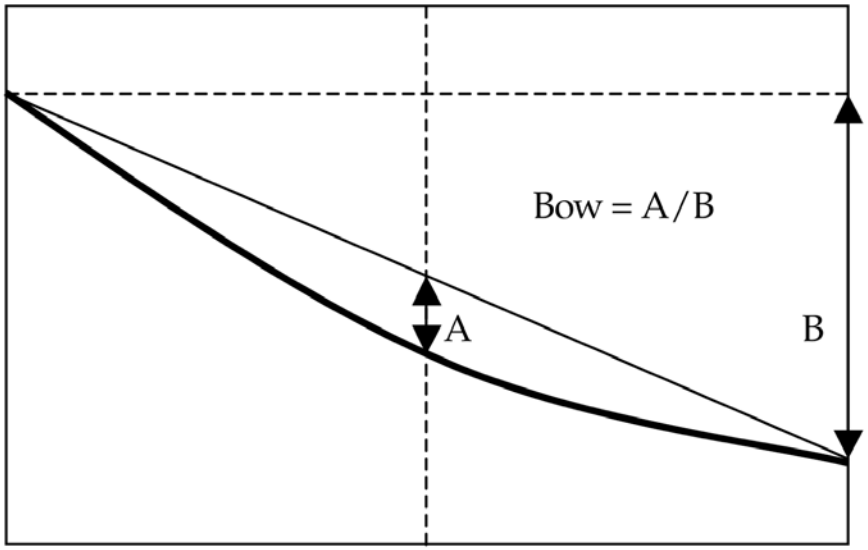
Data Set	Black		Cyan		Magenta		Yellow		Isometric	
	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE	Avg ΔE	Max ΔE
ANSI CGATS TR001	0.37	1.25	0.43	1.25	0.53	1.41	0.64	1.37	0.46	1.14
ANSI CGATS DTR004	0.61	1.93	0.55	1.31	1.04	1.98	0.94	2.03	0.71	1.49
FOGRA27 (Coated #1)	0.13	0.38	0.21	0.50	0.44	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

Bow and Twist

- Our tone reproduction model has four parameters - highlight value, shadow value, highlight contrast and shadow contrast
- Bow and Twist are derivative measures that portray this model in a more conventional way

Bow

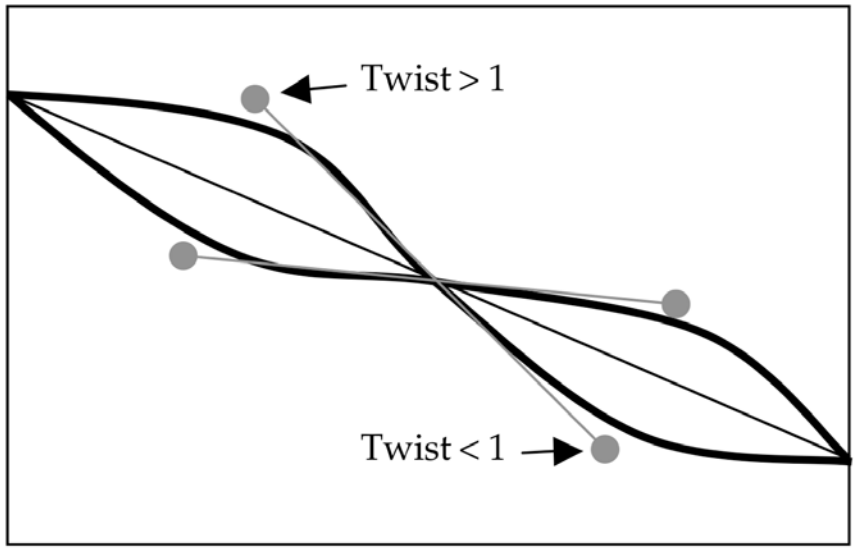
Bow is similar to midtone TVI. Values greater than 0 are fuller, and values less that 0 are sharper. The figure below illustrates bow geometrically.



A straight line curve has a bow of 0.

Twist

Twist is a relative measure of mid-tone contrast. Curves with values significantly greater than or less than one will be S-shaped. Geometrically, it will appear that the curve was "twisted" around the midpoint. This is illustrated in the figure below.



The curve with the steeper slope has a twist greater than one, while the other curve has a twist less than one. A straight line curve has a twist of one, by definition.

What Pressmen Want

- Don’t ask a pressman to print solid ink levels specified as Lab values
- That’s an impossible task, and the pressman will no longer respect you
- Seriously, pressmen need a single-valued tone measure derived from colorimetry
- We’ve worked on this problem, and found a good solution

Colorimetric Tone Value (CTV)

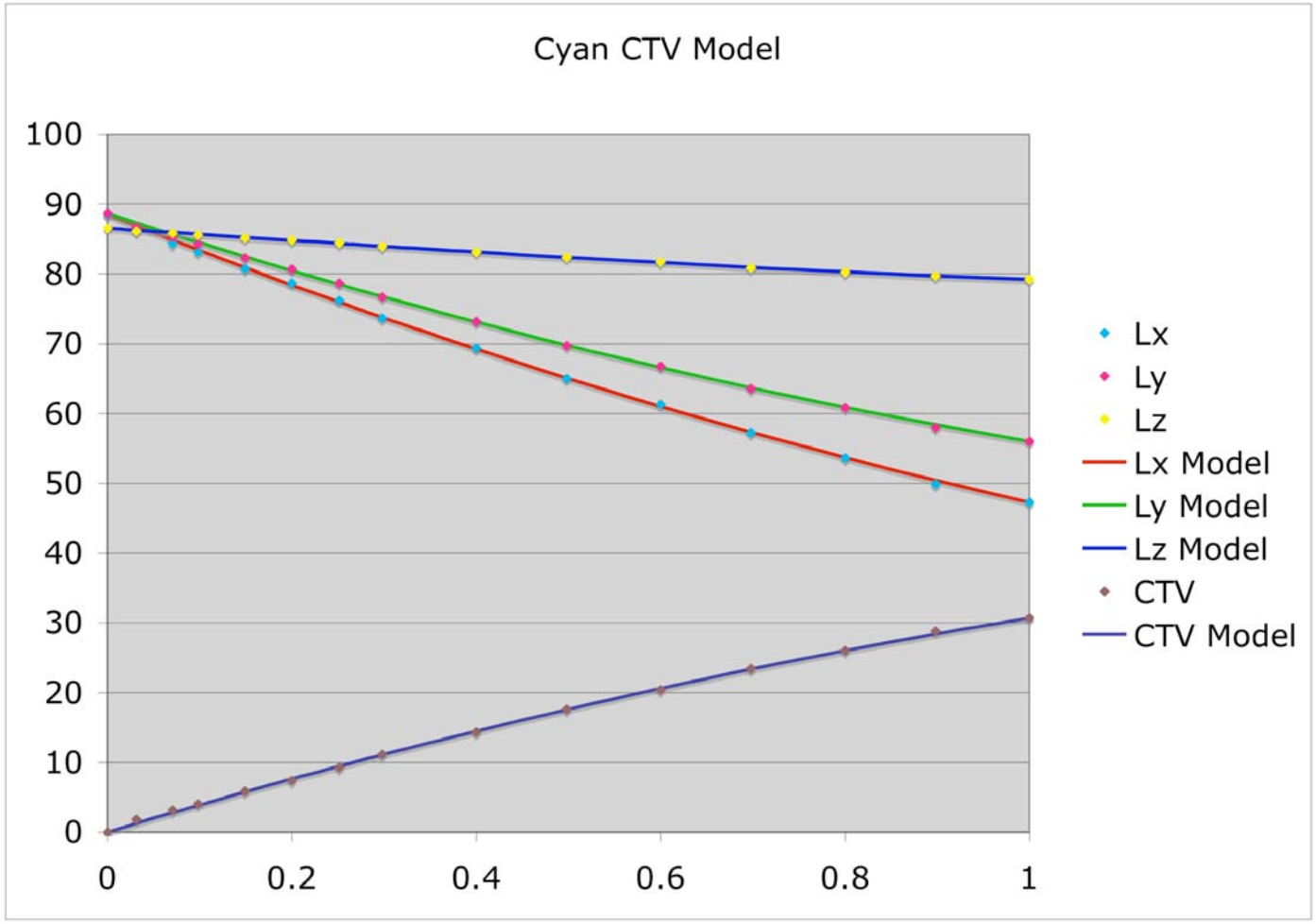
- CTV calculation (relative to paper white)

  The paper white measurements are L_{xp}, L_{yp}, L_{zp}:

$$CTV = \sqrt{\frac{(L_{xp} - L_x)^2 + (L_{yp} - L_y)^2 + (L_{zp} - L_z)^2}{3}}$$

- CTV values are between 0 (paper white) and 100 (perfect black)
- Simple geometric interpretation in LxLyLz color space

TR 001 CTV vs. %-dot



CTV Properties

- Single-valued tone measure
- Computed from Lab or xyz values
- No RGB filter response to choose
- Works for both process and spot colors
- Inherently achieves the “best match” to an Lab value
- Absolute or relative to paper white

PressCal6 Test Target

PressCal Software

- Makes tone reproduction curves and device link profiles to match a reference
- Uses same measurement data as the Report Writer software
- Generates native format TRC files for Brisque, Prinergy, RAMPage and Harlequin
- Sophisticated matching options

PressCal Software

- Generates device links for CMY/K to CMY/K transforms
- Correctly “warps” CMY color space for perfect isometric match
- Preserves purity and saturation of process colors and 2/C overprints
- Preserves integrity of black printer
- Enables printers to “normalize” incoming CMYK files

Looking for Partners

- Doppelganger LLC is a small (3 man) consulting firm
- We plan to offer our software tools as a web service (ASP model)
- We are looking for consulting partners who would refer business in exchange for free use of these tools