

Optimal Tone Reproduction Curves for Color Printing

William B. Birkett, Doppelganger, LLC

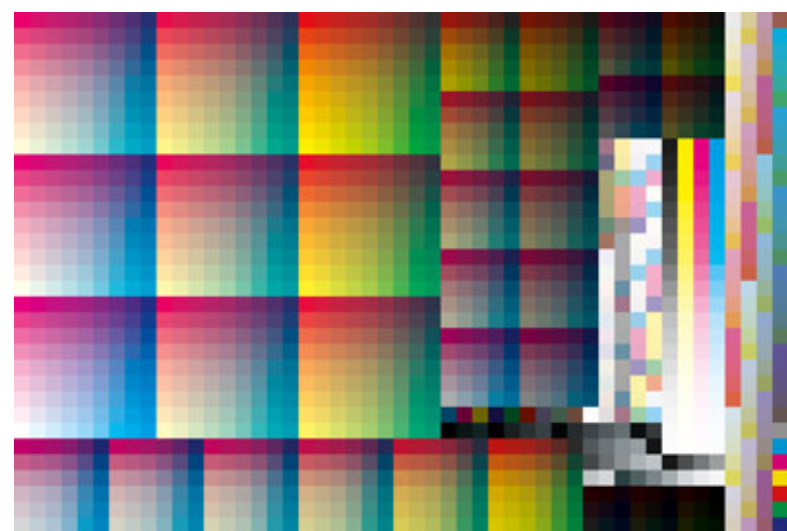
And

Charles Spontelli, BGSU



The Problem

Reference Data Set



CMYK → L*a*b*

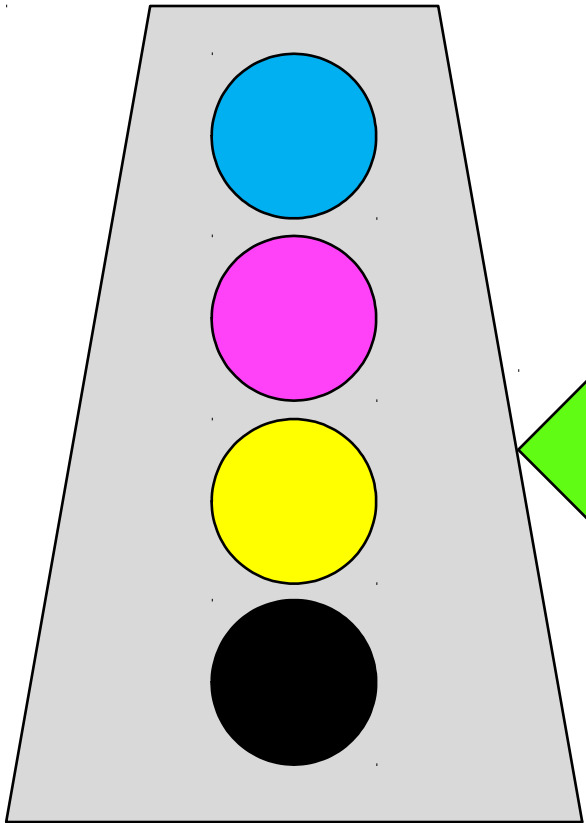
Proofs are color managed to match a reference data set such as GRACoL2013 or FOGRA 51

Inkjet Printer

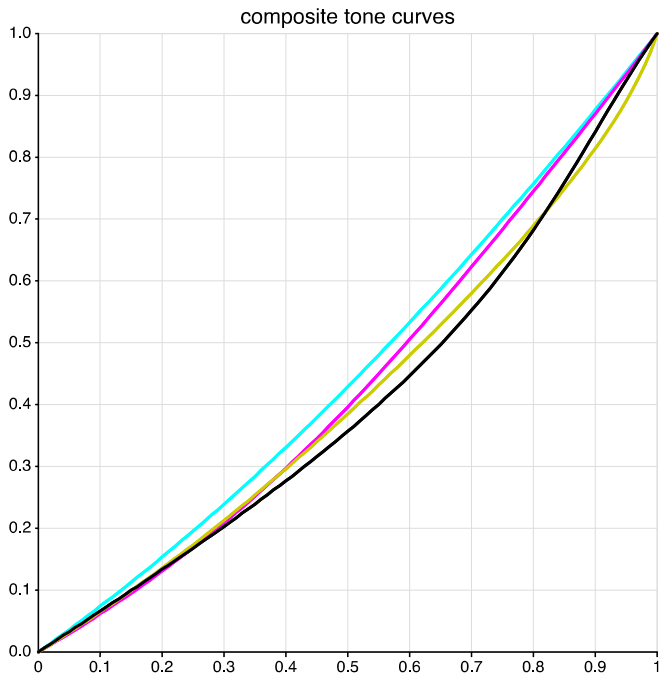


Proof

Press



Press Sheet



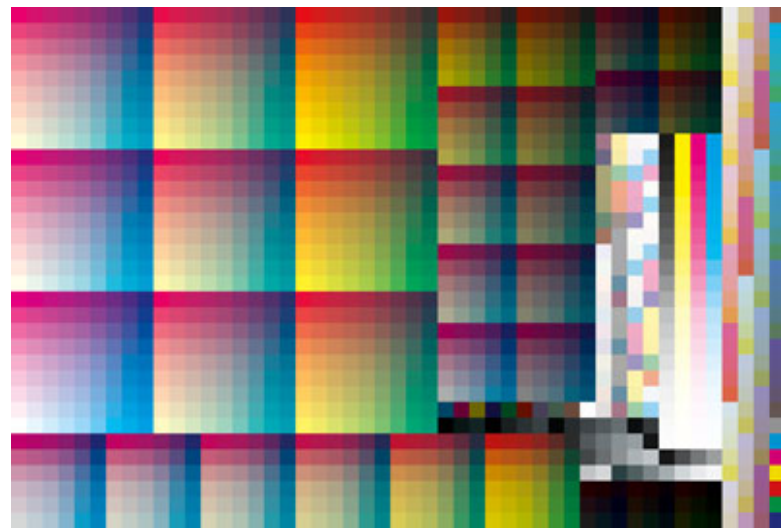
Tone Curves



Visual Match

The Problem

Reference Data Set



CMYK $\rightarrow$ $L^*a^*b^*$

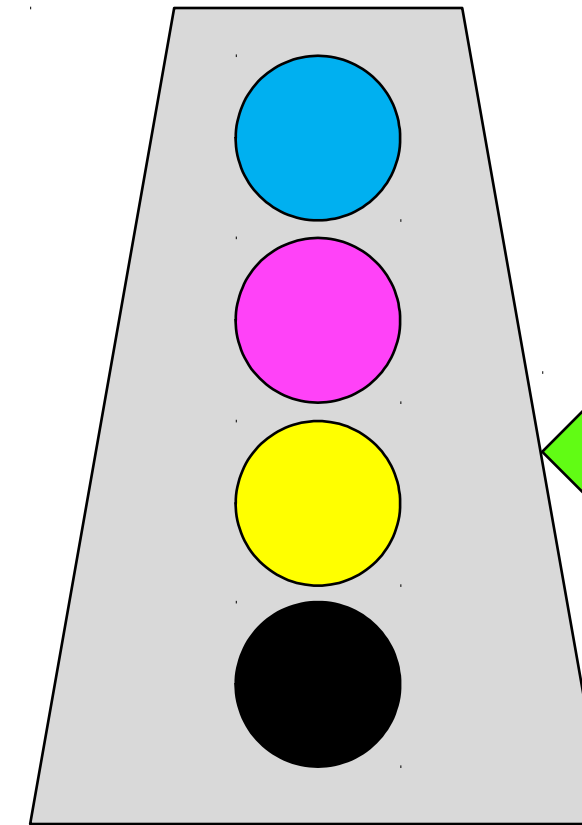
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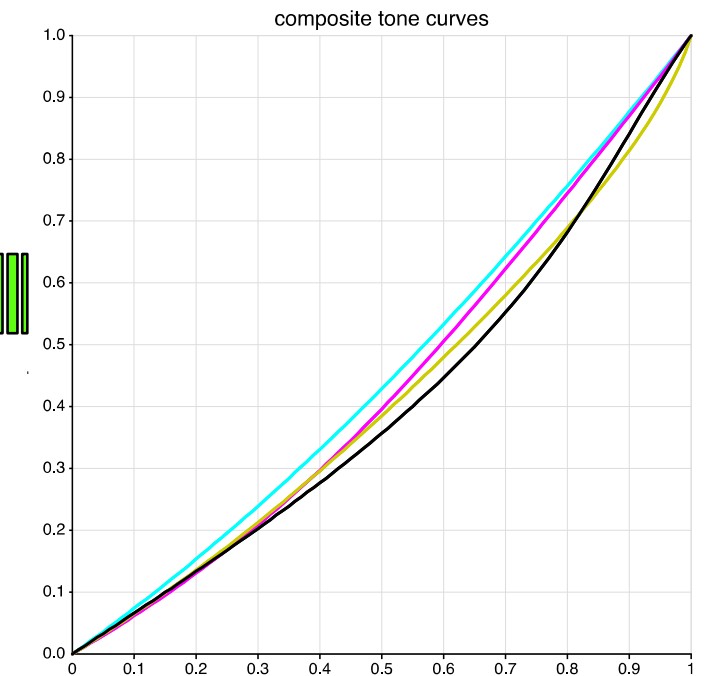


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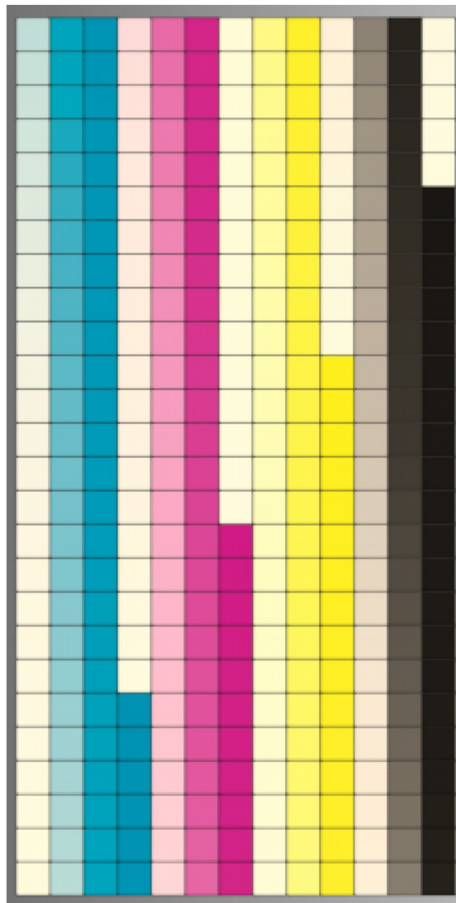
Tone Curves

How do we make tone curves to match our proofs on press?

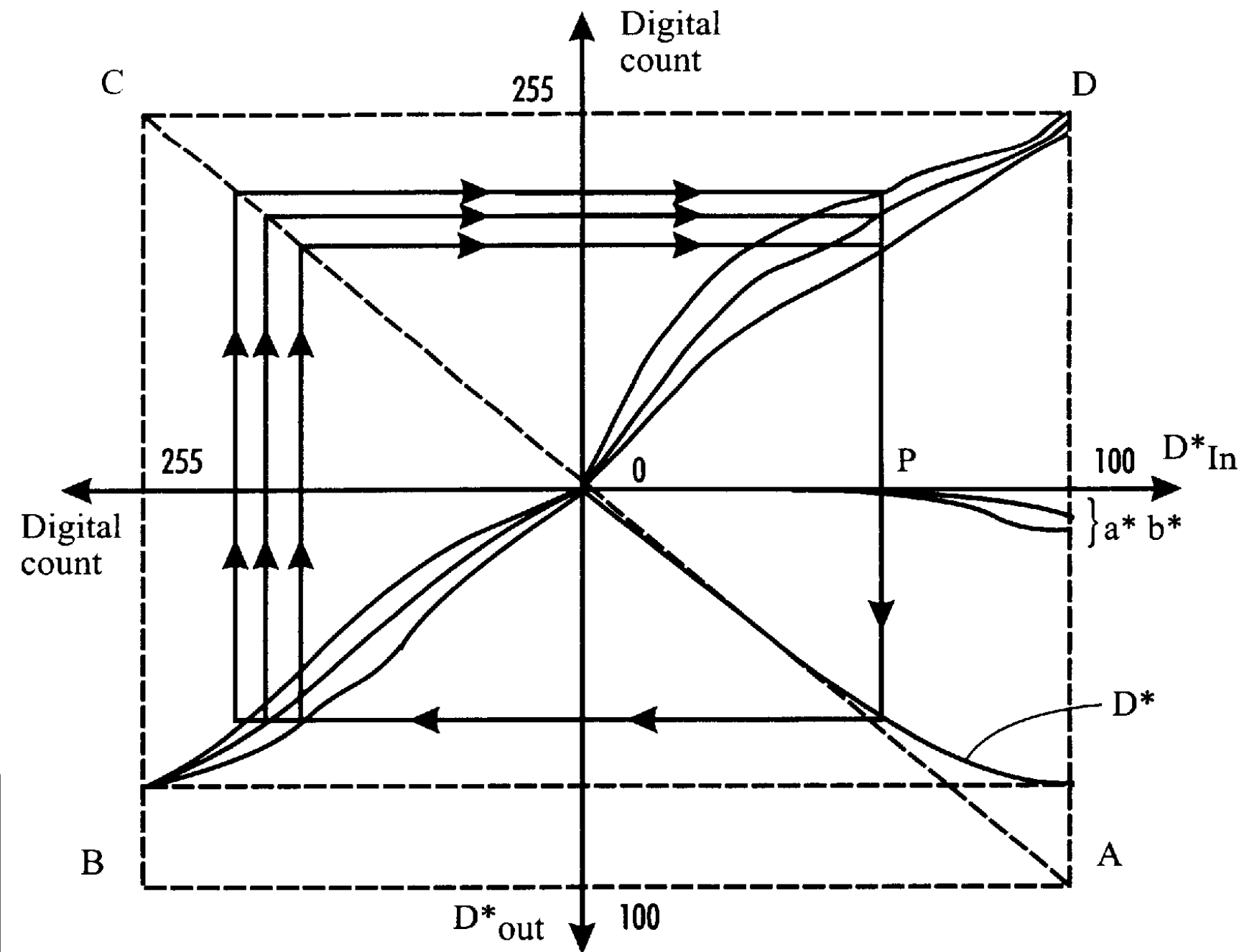
Visual Match

Existing Solutions (ISO/TS 10128:2009)

TVI

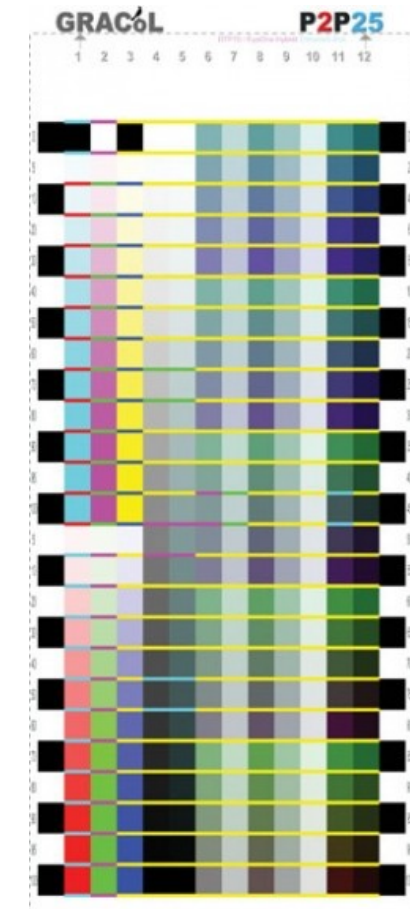


Print and measure process color ramps. Make curves to achieve target TVI values.



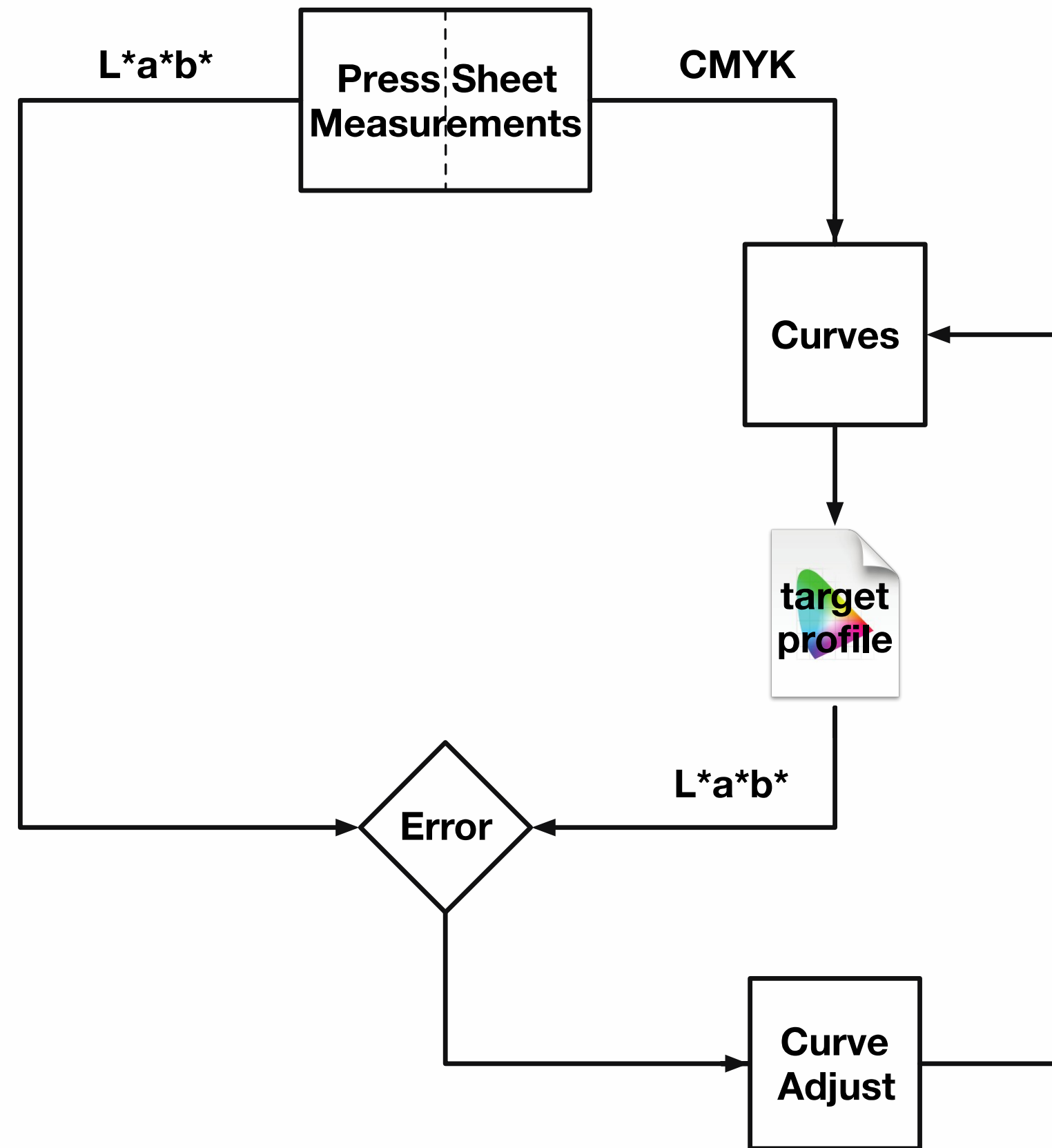
Jones Diagram

Near-Neutral



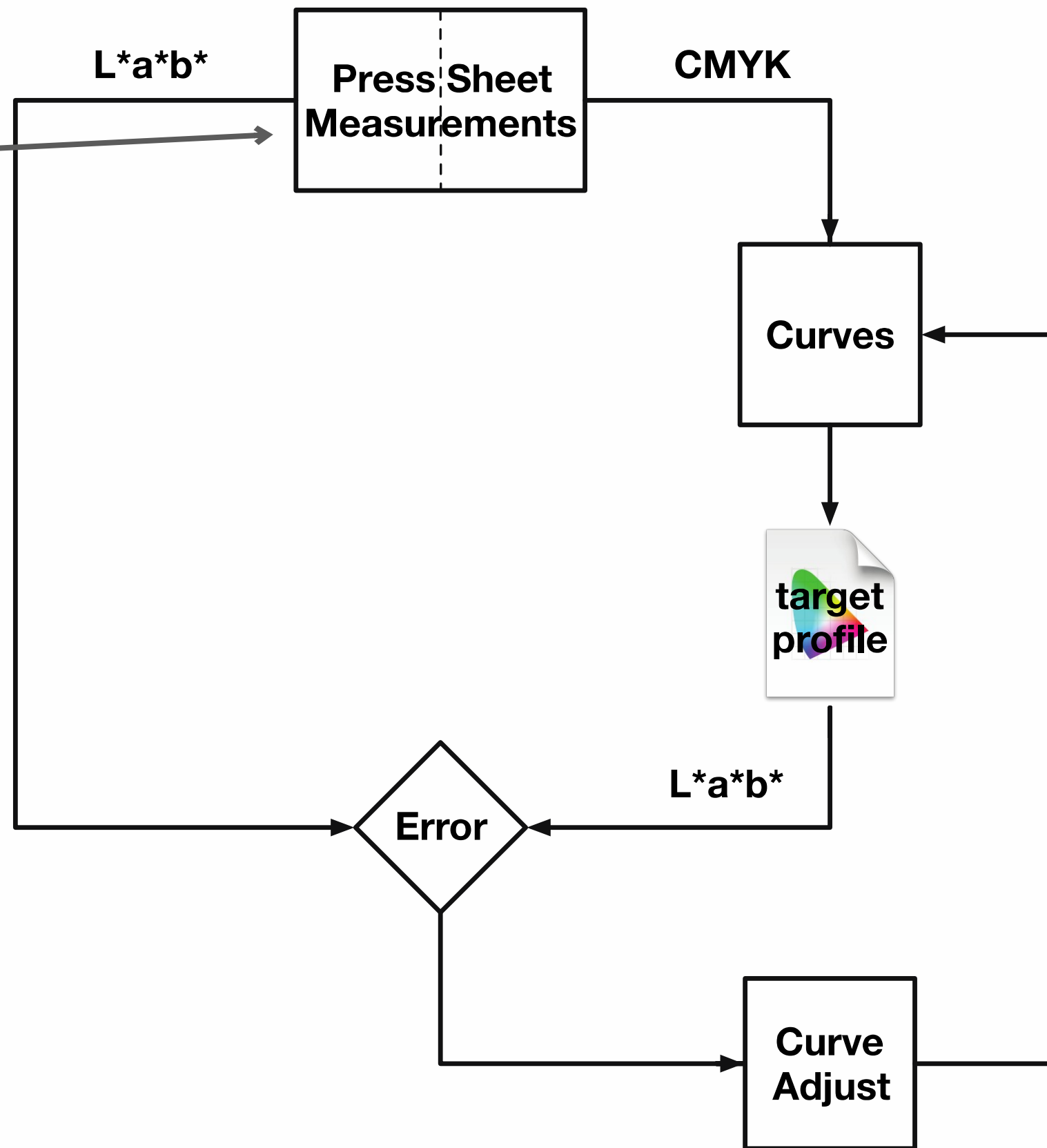
Print and measure CMY gray and black ramps. Make curves to achieve target gray balance and NPDCs.

The OPTIMAL Method

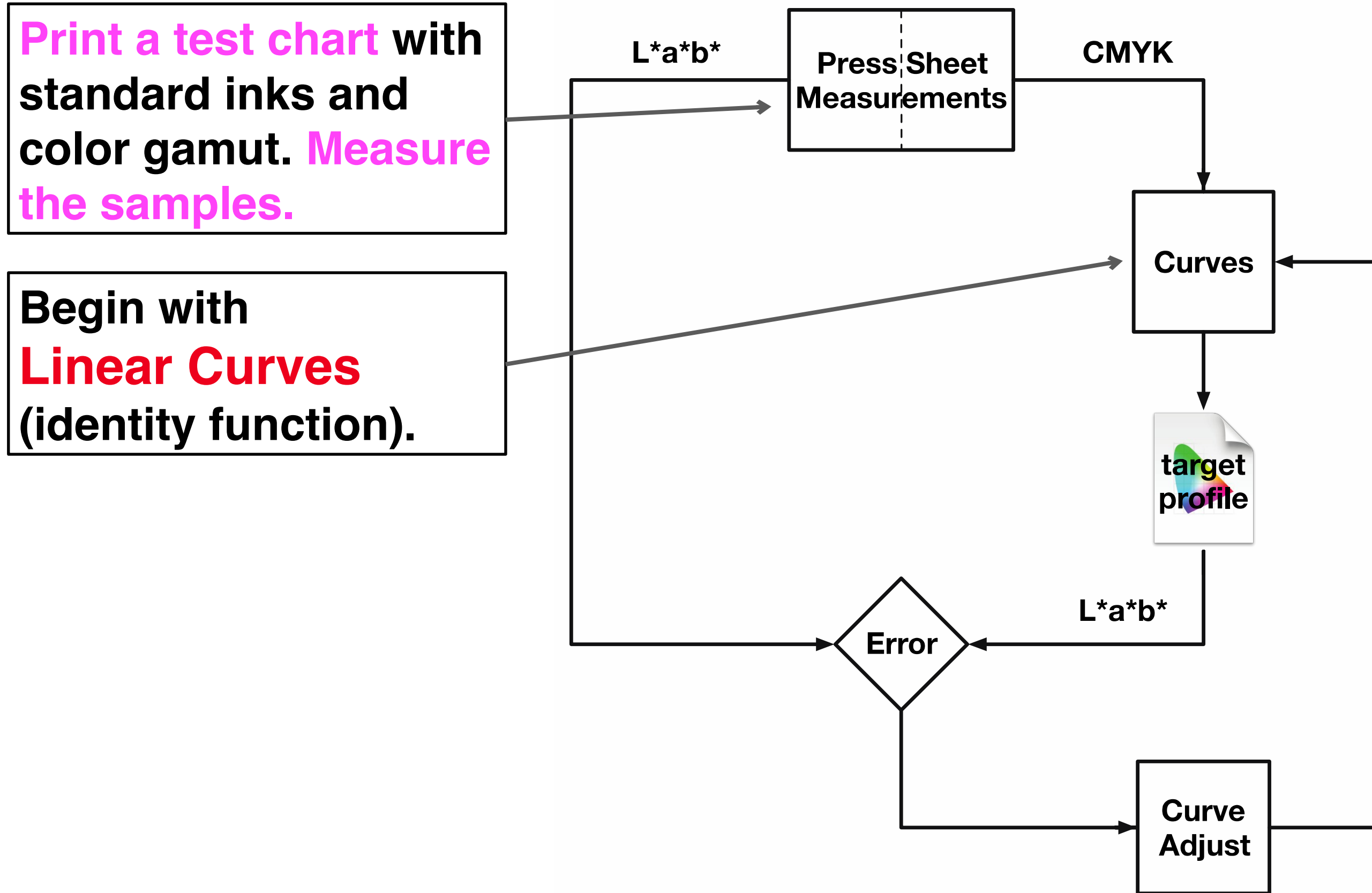


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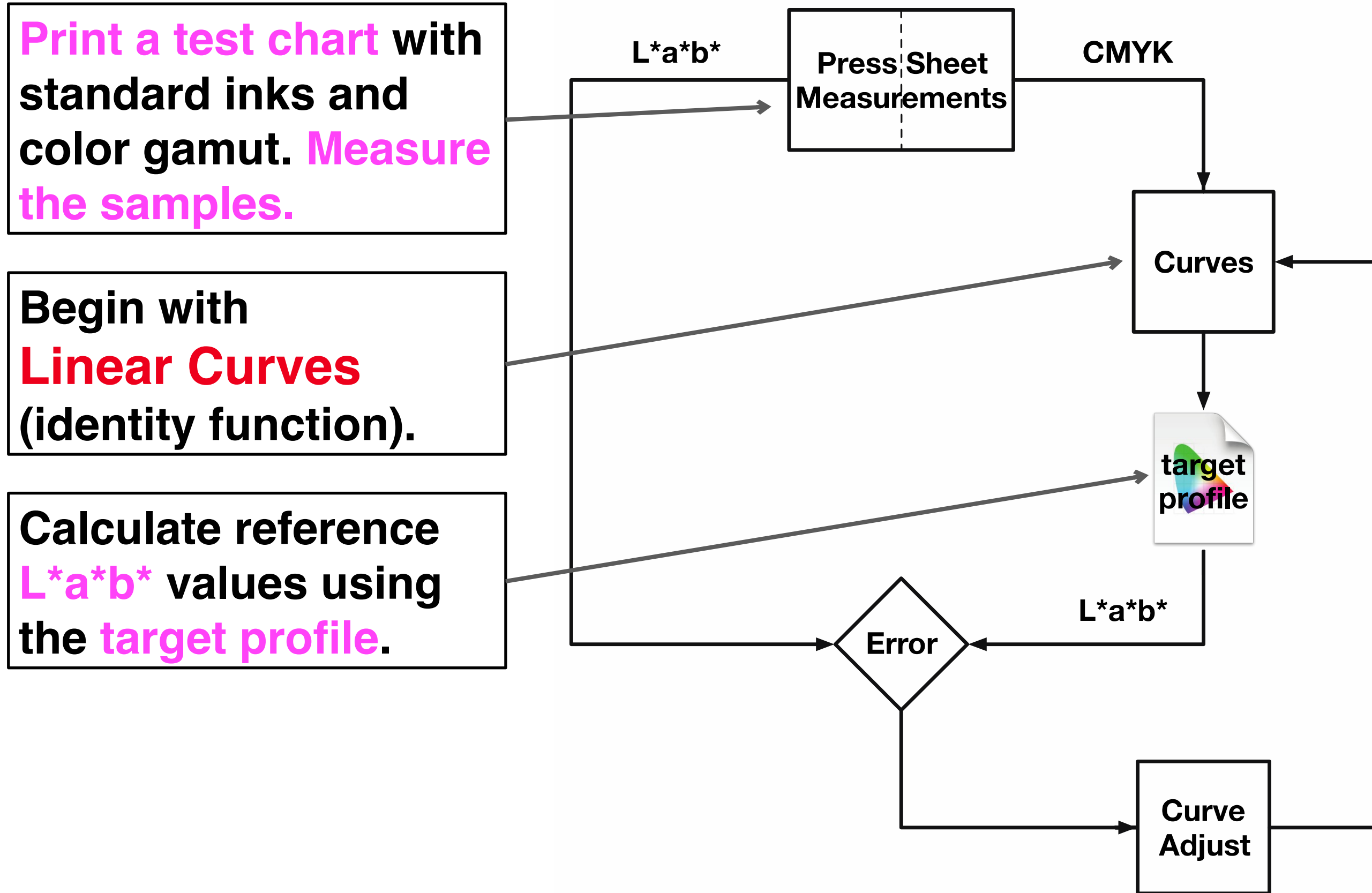
Print a test chart with standard inks and color gamut. Measure the samples.



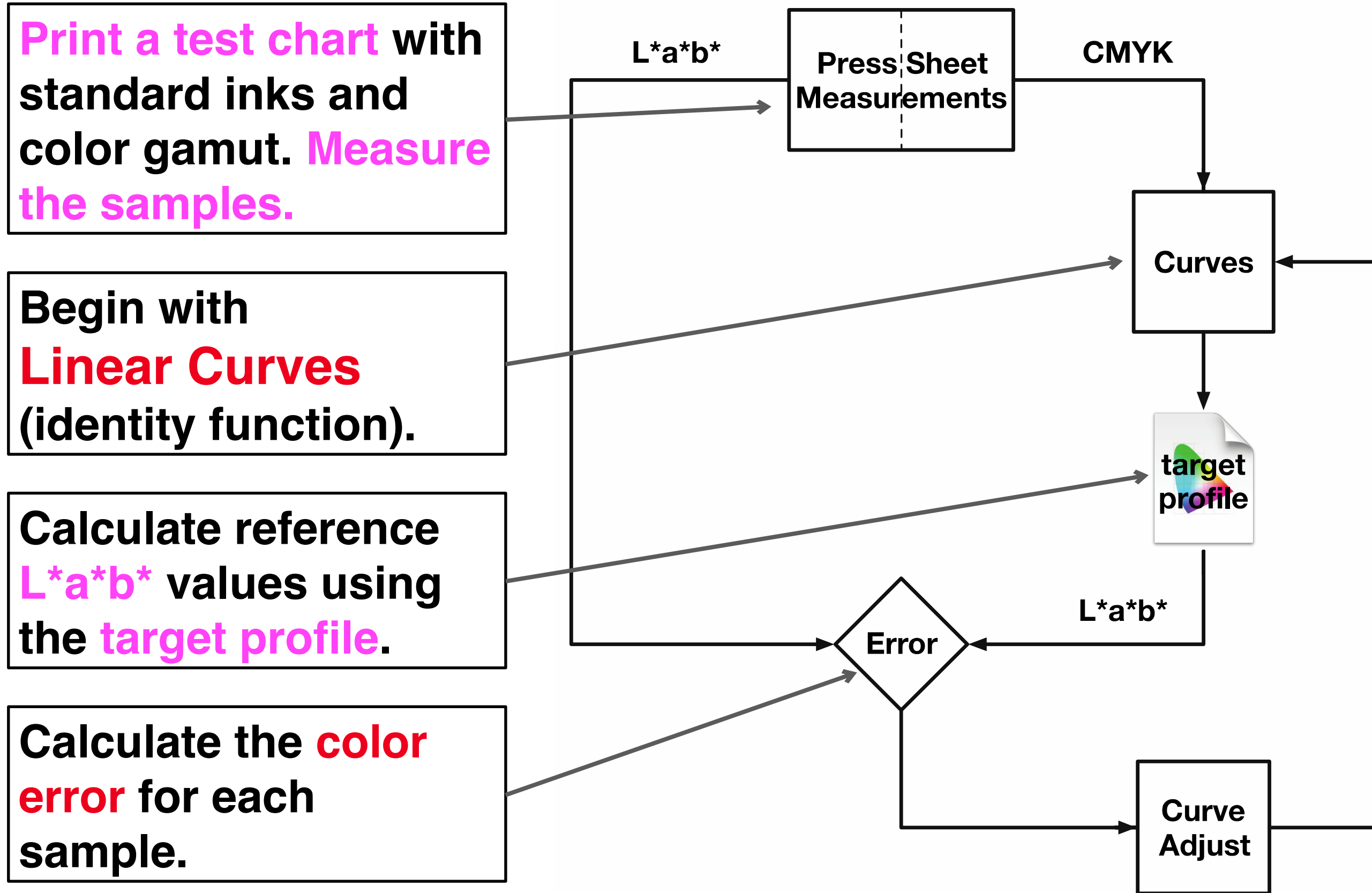
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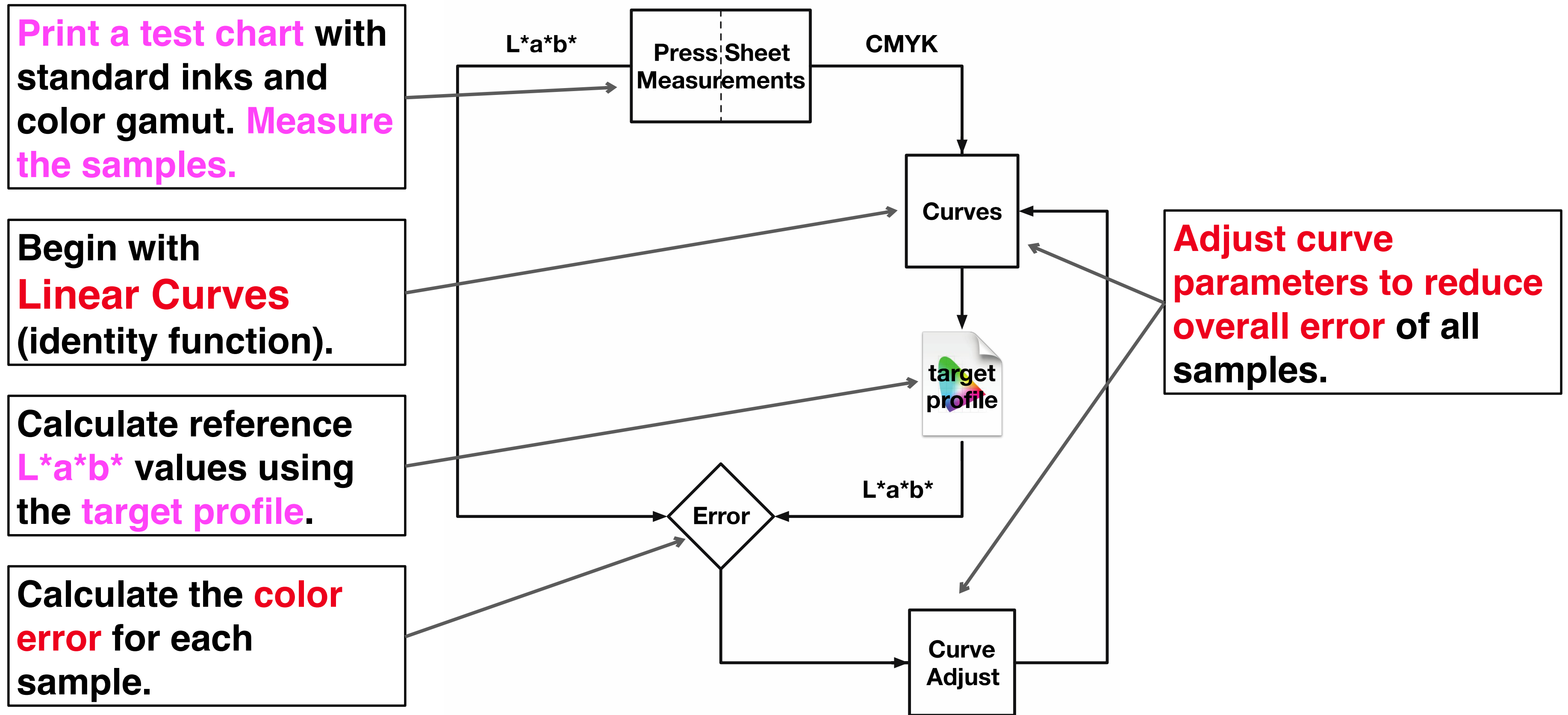
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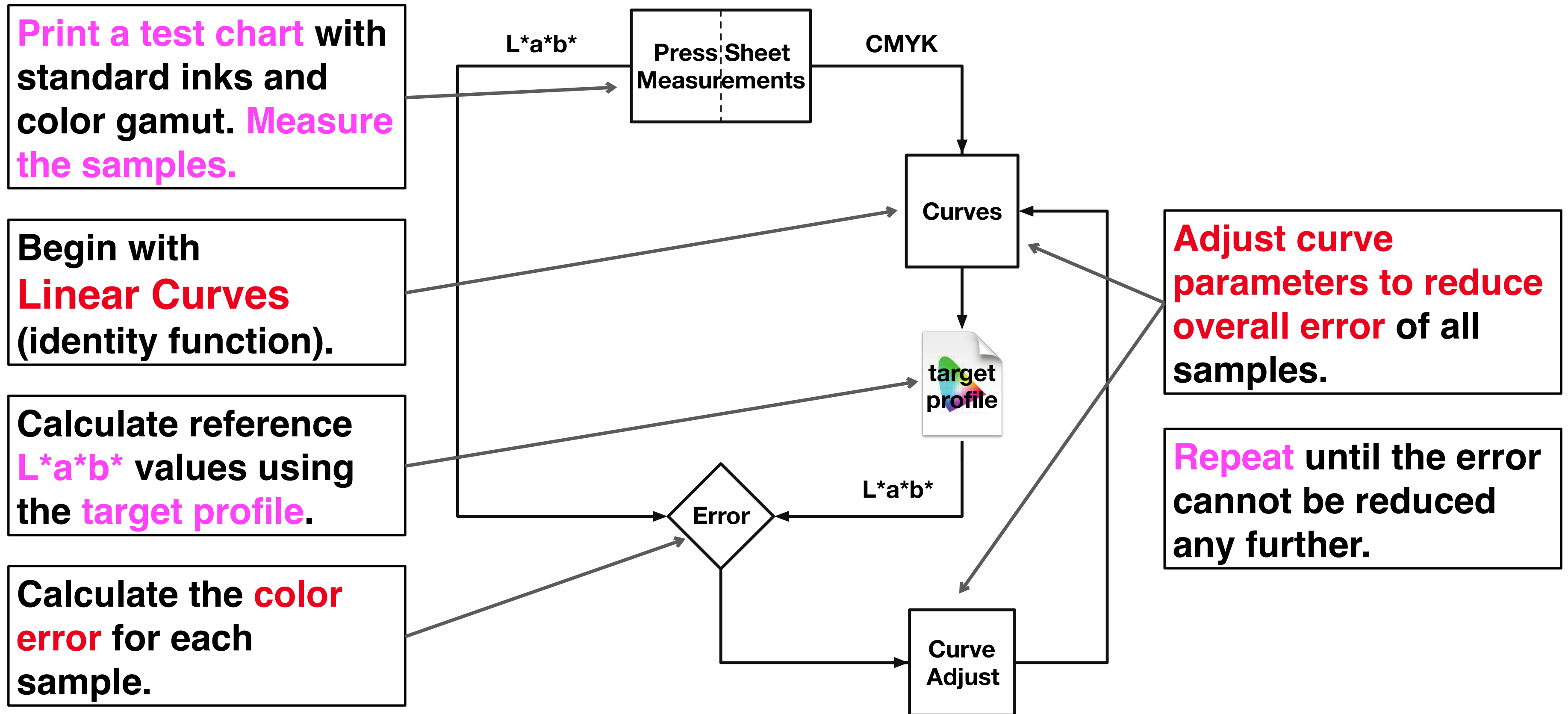
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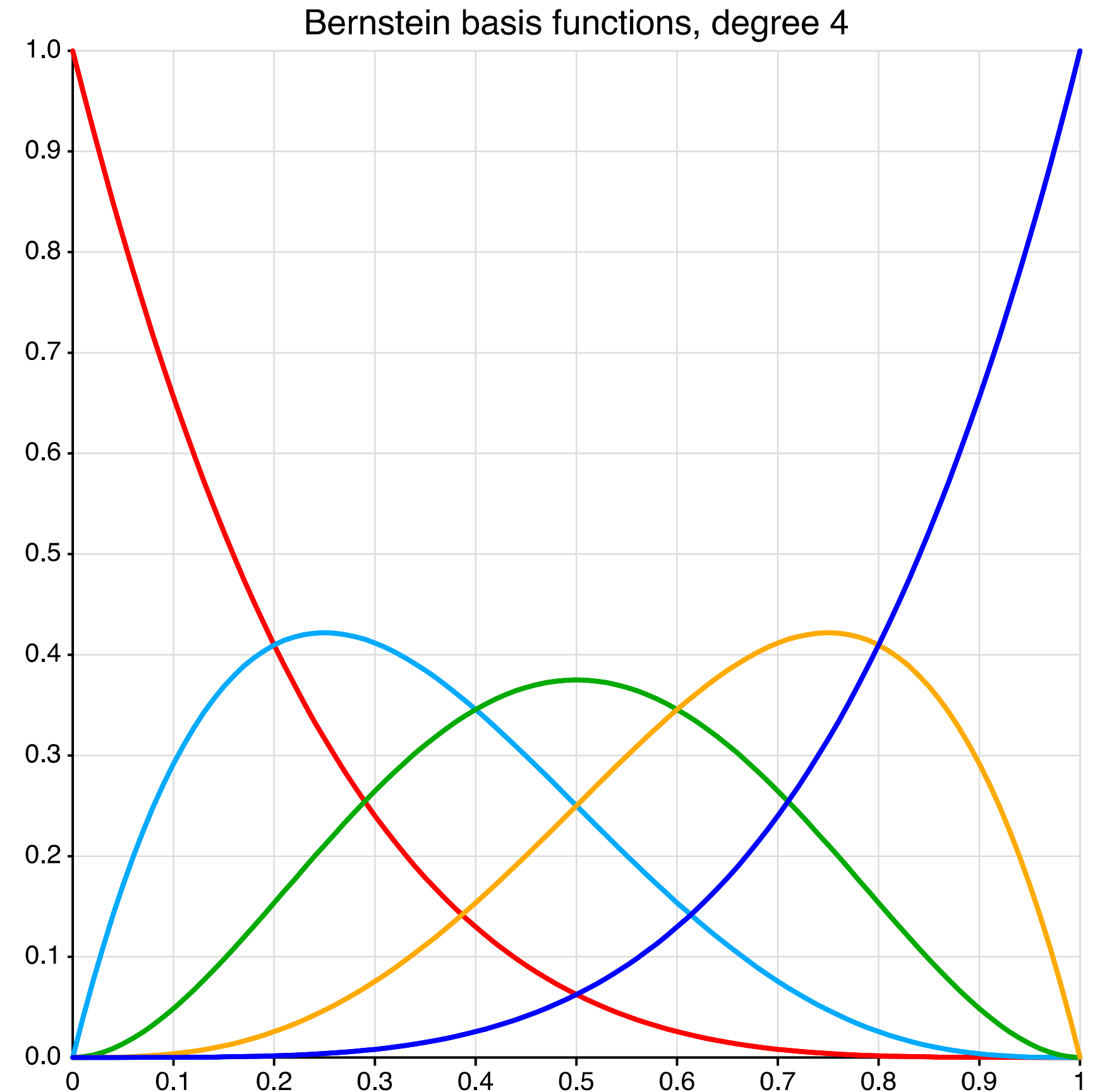


The OPTIMAL Method



Parametric Curves

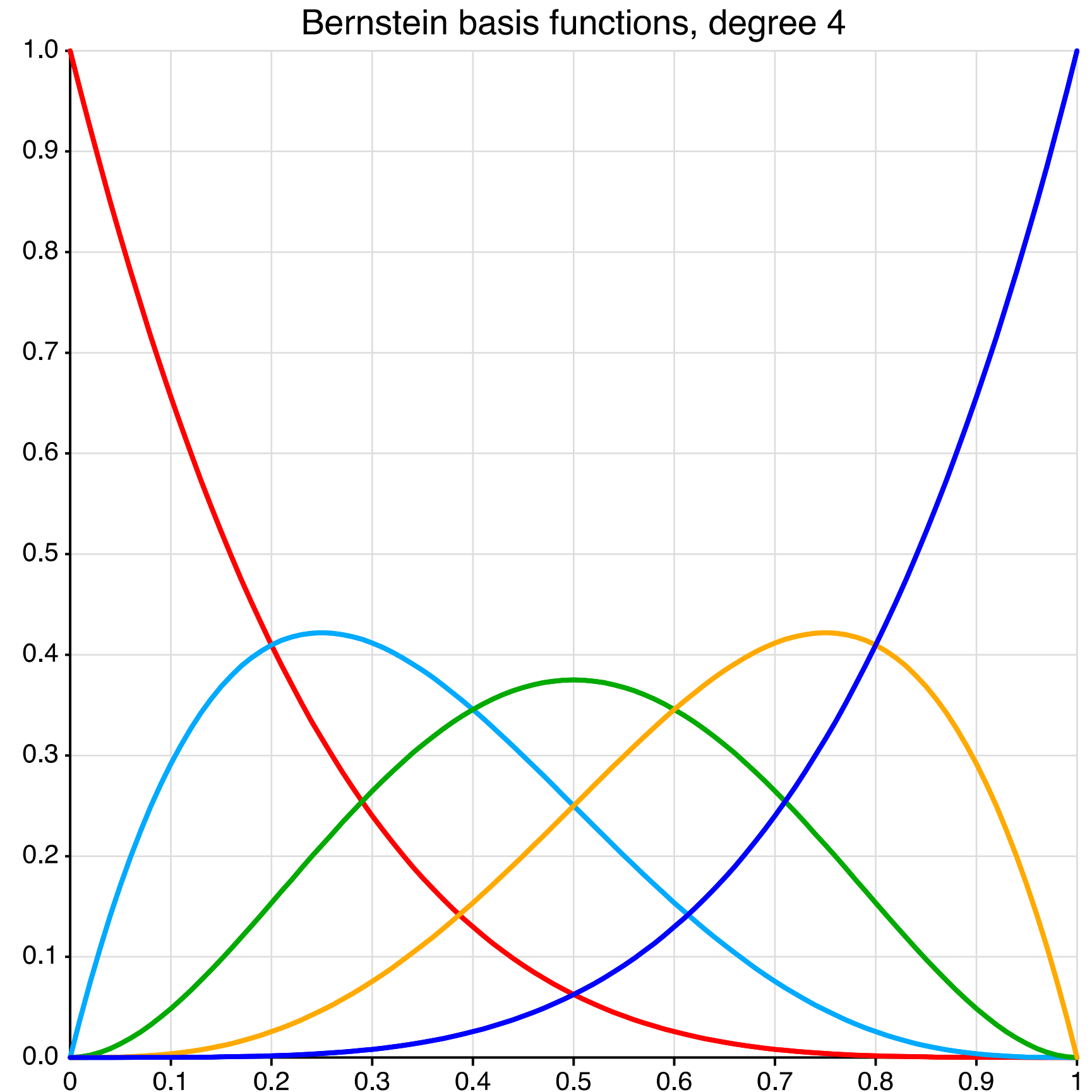
- **Bernstein Polynomials**
 - **Model Tone Curves**
 - **Bernstein Basis Functions**
 - **Smoothly divide tones into regions**



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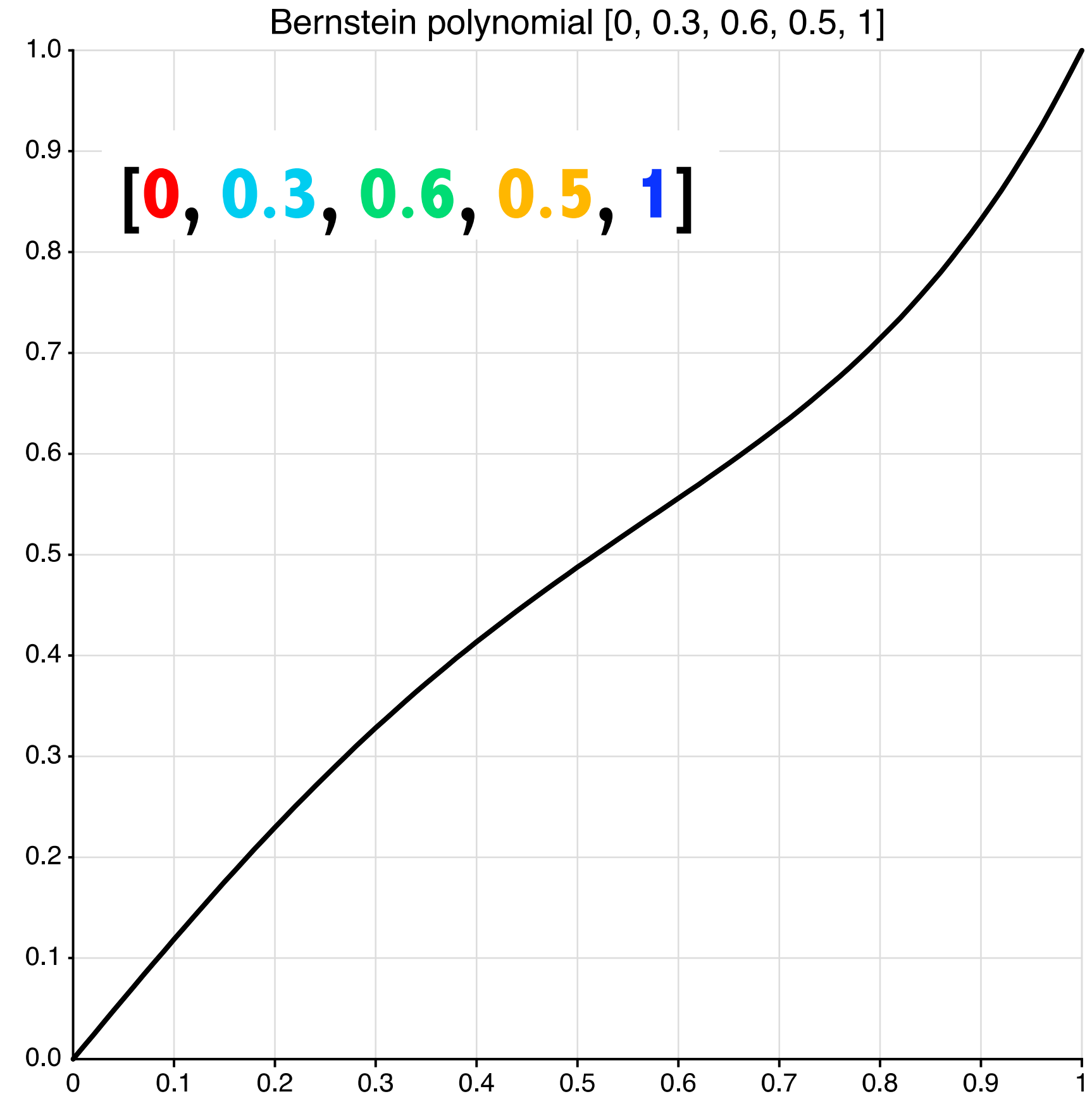
Each tone curve is a linear combination of the basis functions. The curve is defined by an array of coefficients, e.g. [0, 0.3, 0.6, 0.5, 1] for each function.



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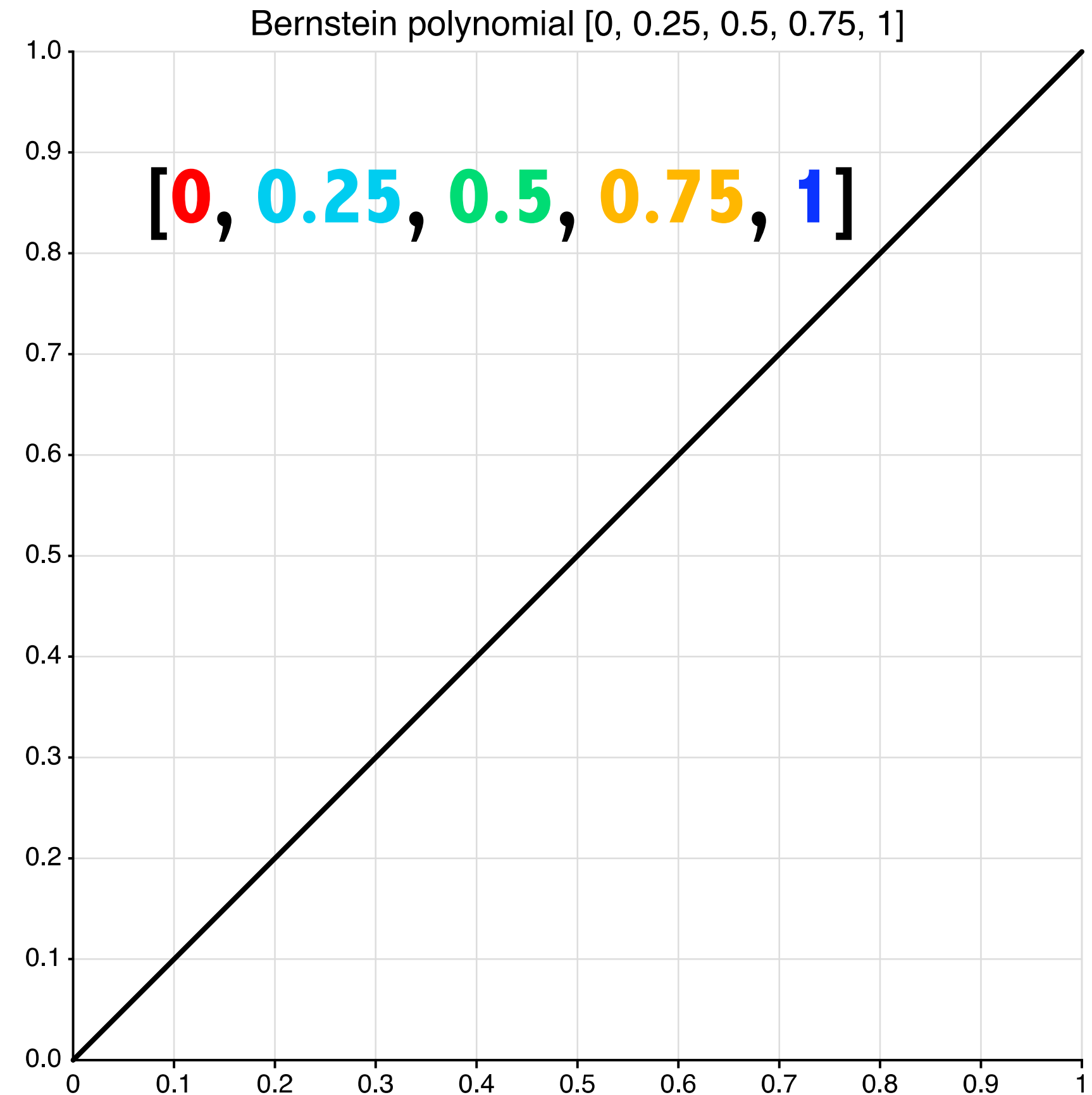


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A surprising Bernstein property is that coefficients spaced equally from 0 to 1 yield the identity function (a 'linear' curve).

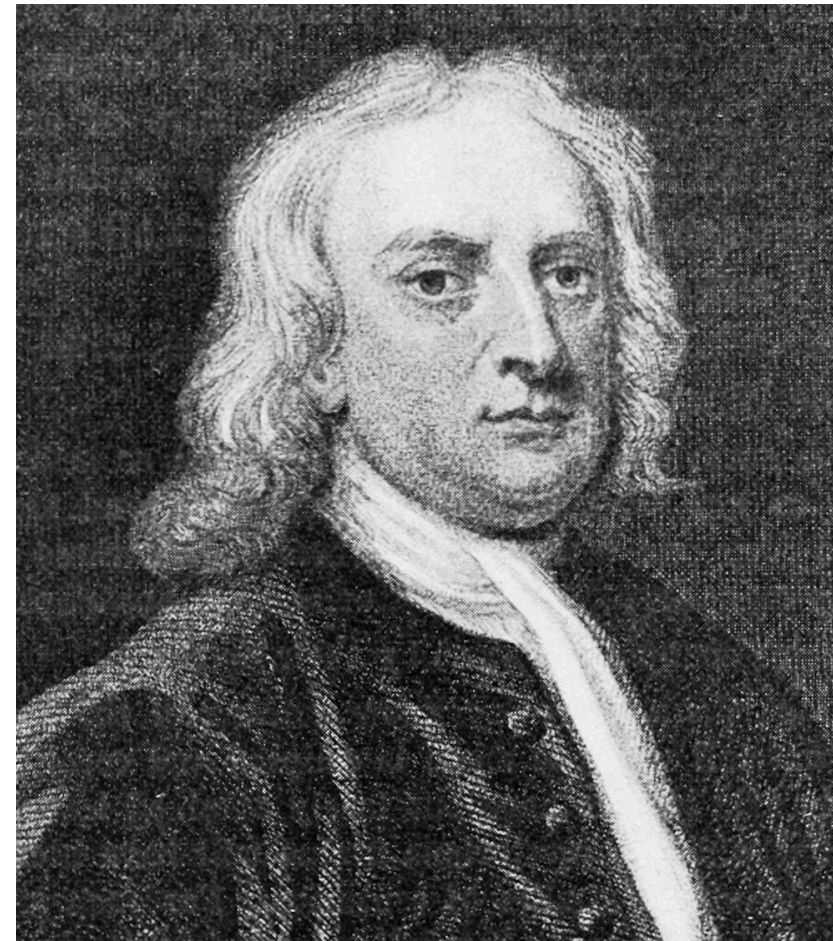


Numerical Optimization

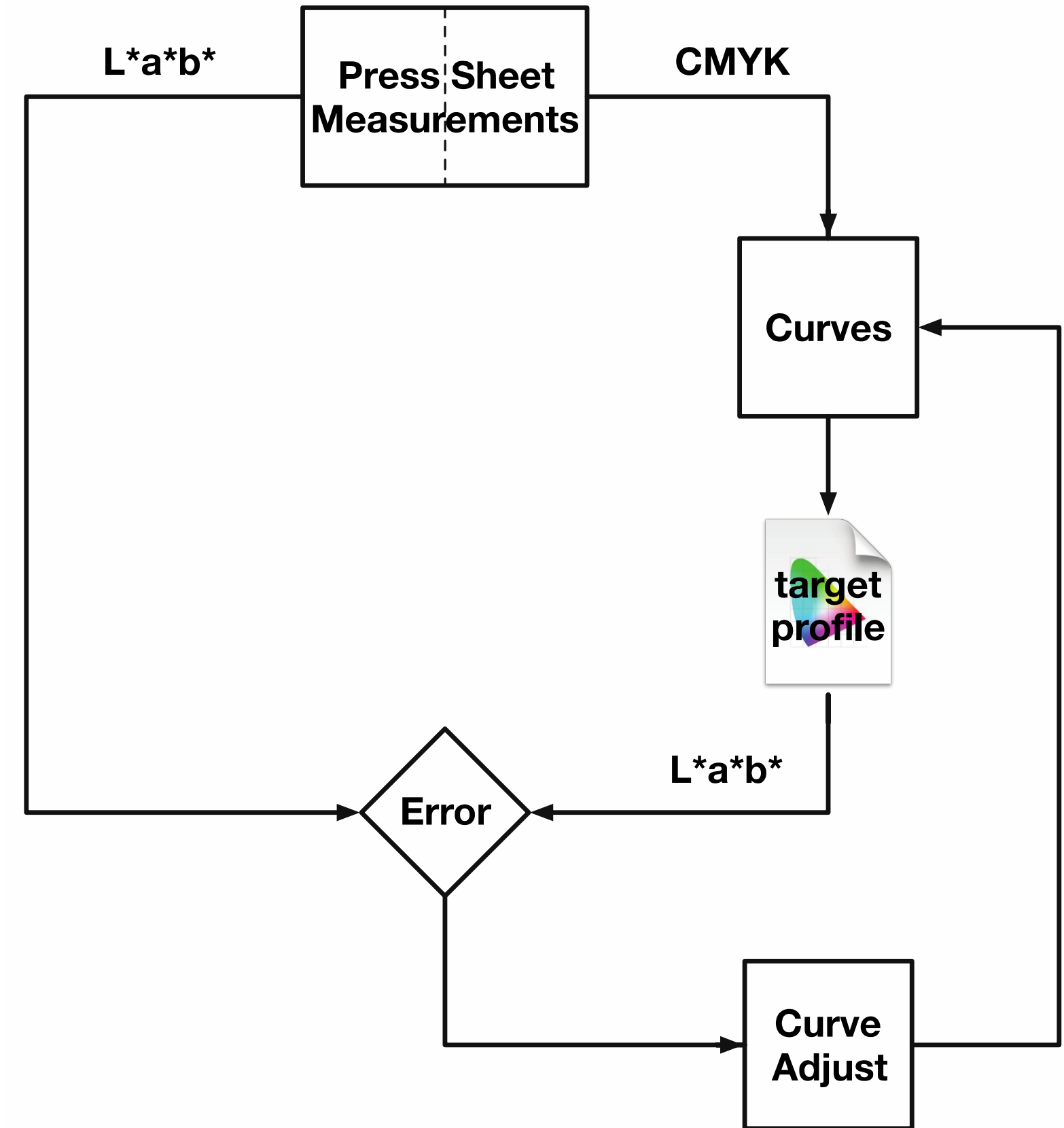
- Tone curves adjusted for **minimum error** using **numerical optimization**.
- **Gauss-Newton method** adjusts all of the curve parameters **simultaneously**.



Carl Friedrich Gauss



Sir Isaac Newton



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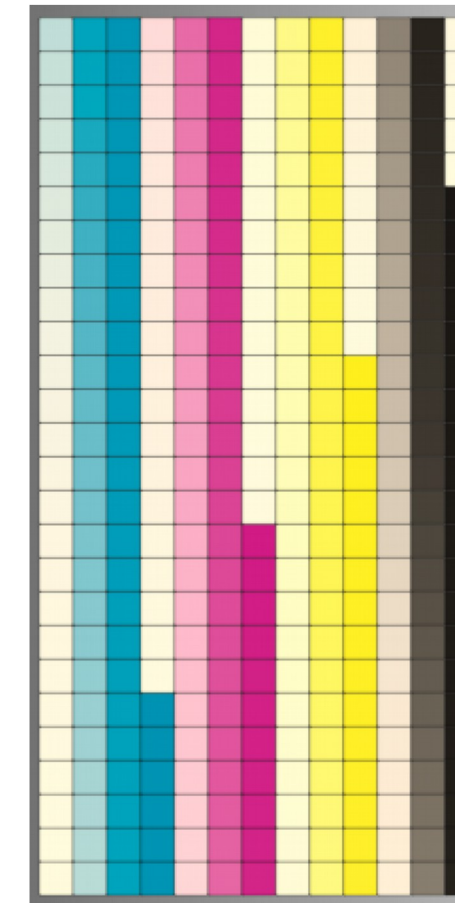
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 - *Goal – minimize **error values** (Δy)*
 - Normal equation - gives a **least squares solution** (for a linear system)
 - Printing process (target profile) is not linear
 - Multiple iterations (4-5) needed to reach minimum error

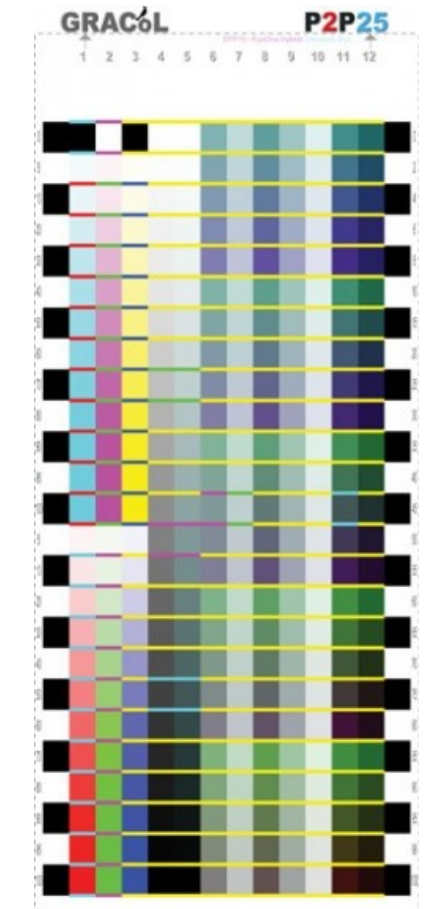
Sample Sets

- **Bound** to the calculation method
 - *TVI – only pure process colors*
 - *Near-Neutral – only gray CMY and pure K colors*

TVI

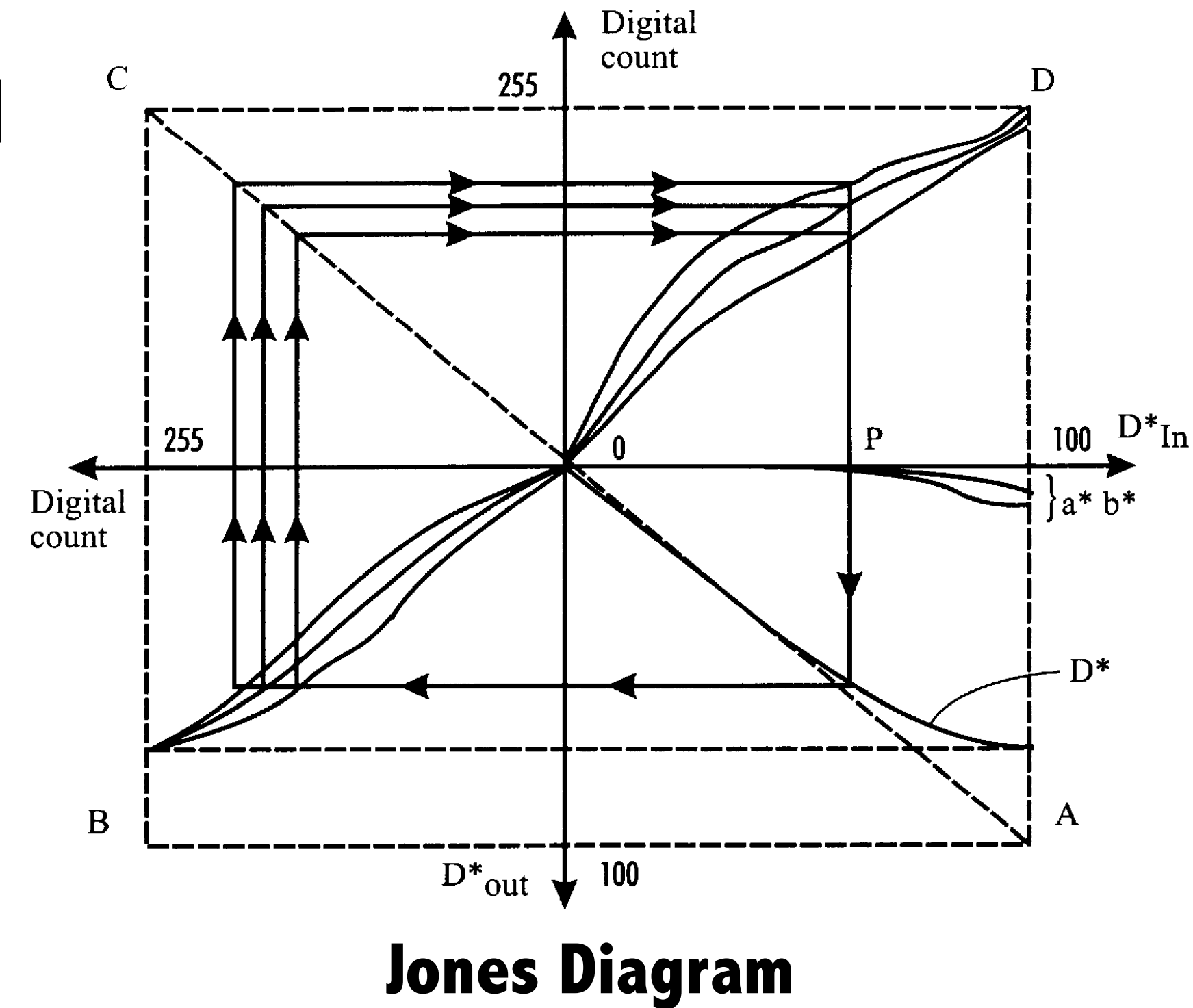


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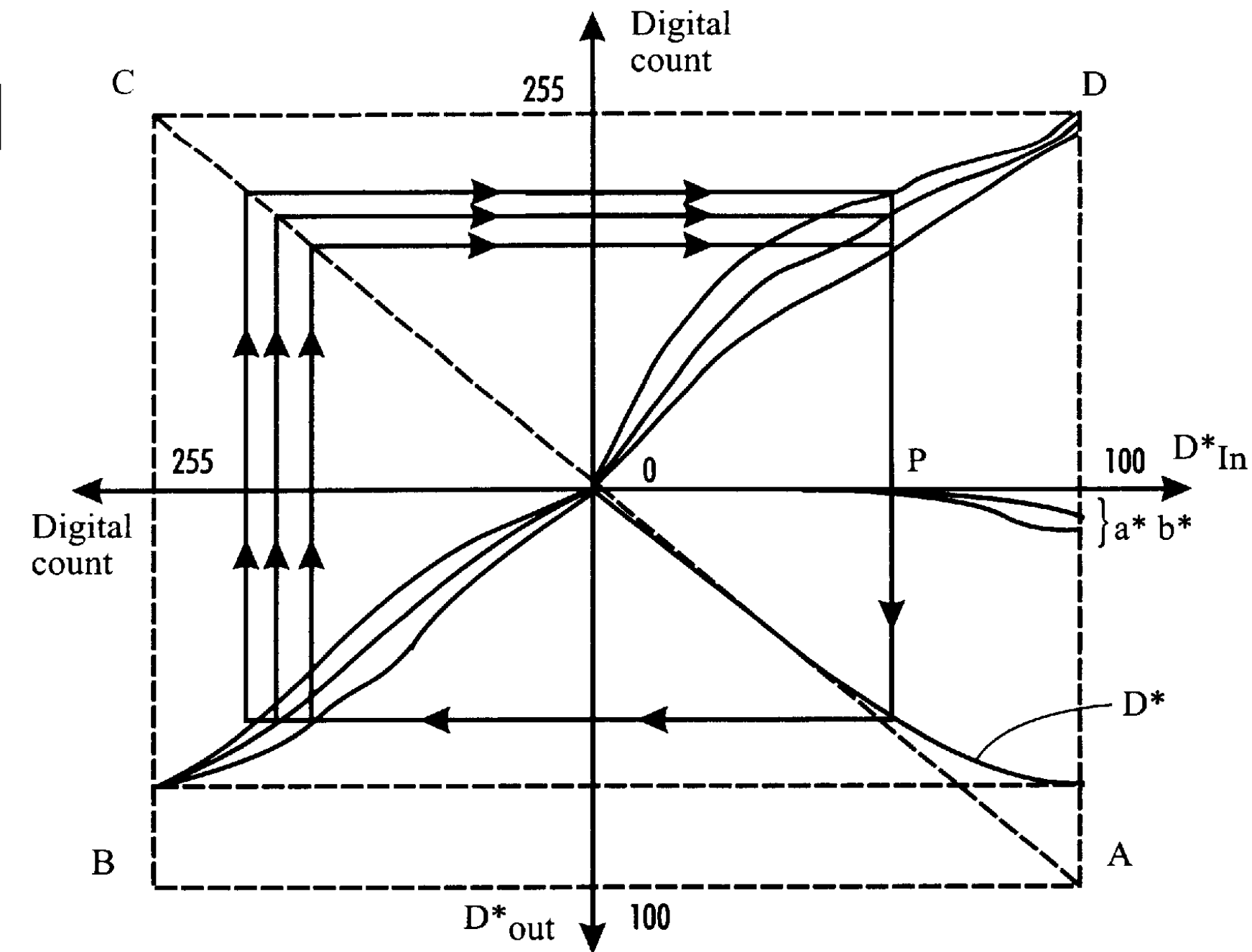
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 - *Murray, 1936*
 - *Elijiw & Archer, 1972*



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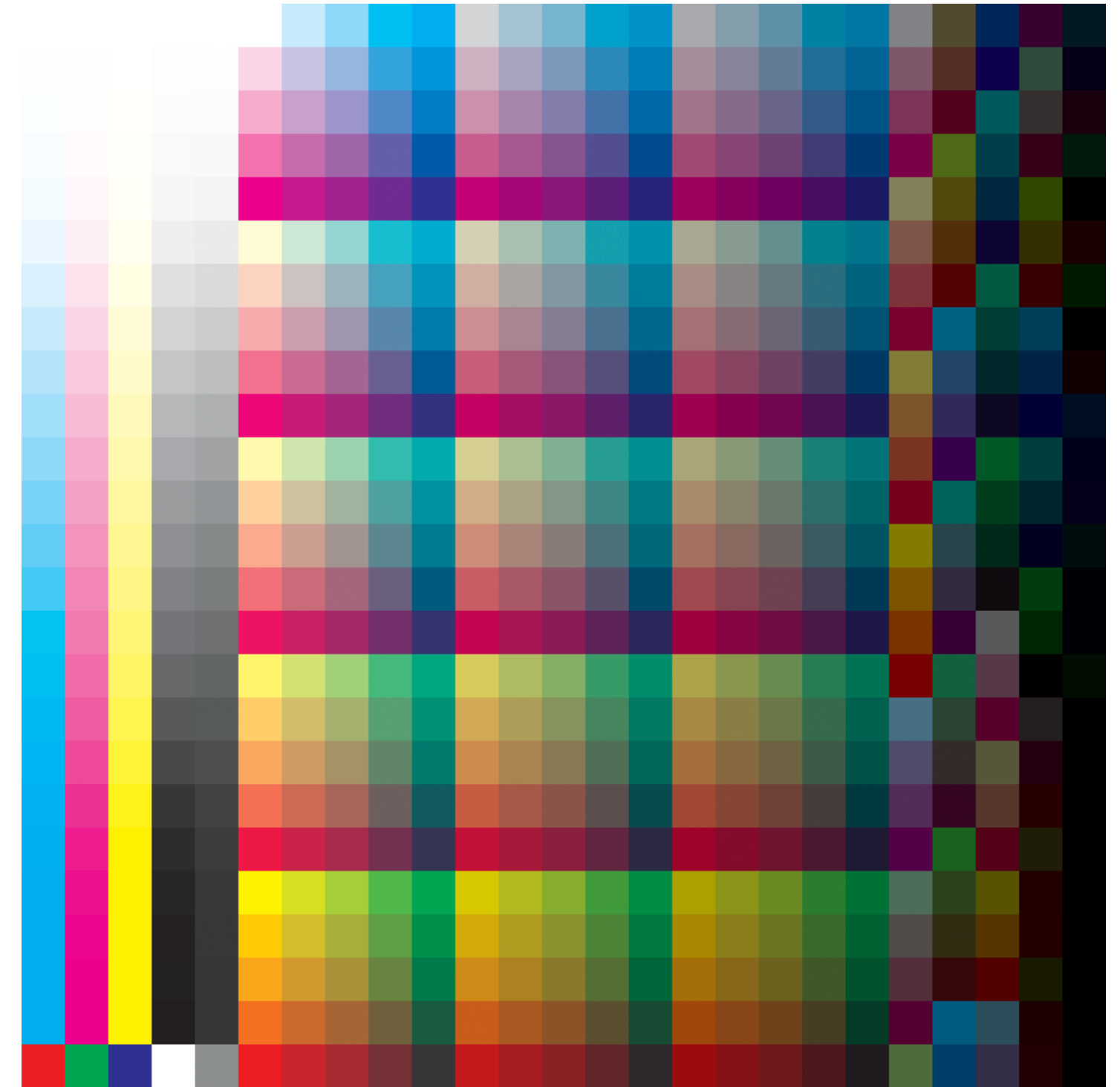
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- Made **obsolete** by computers and colorimetry.



Jones Diagram

Sample Sets

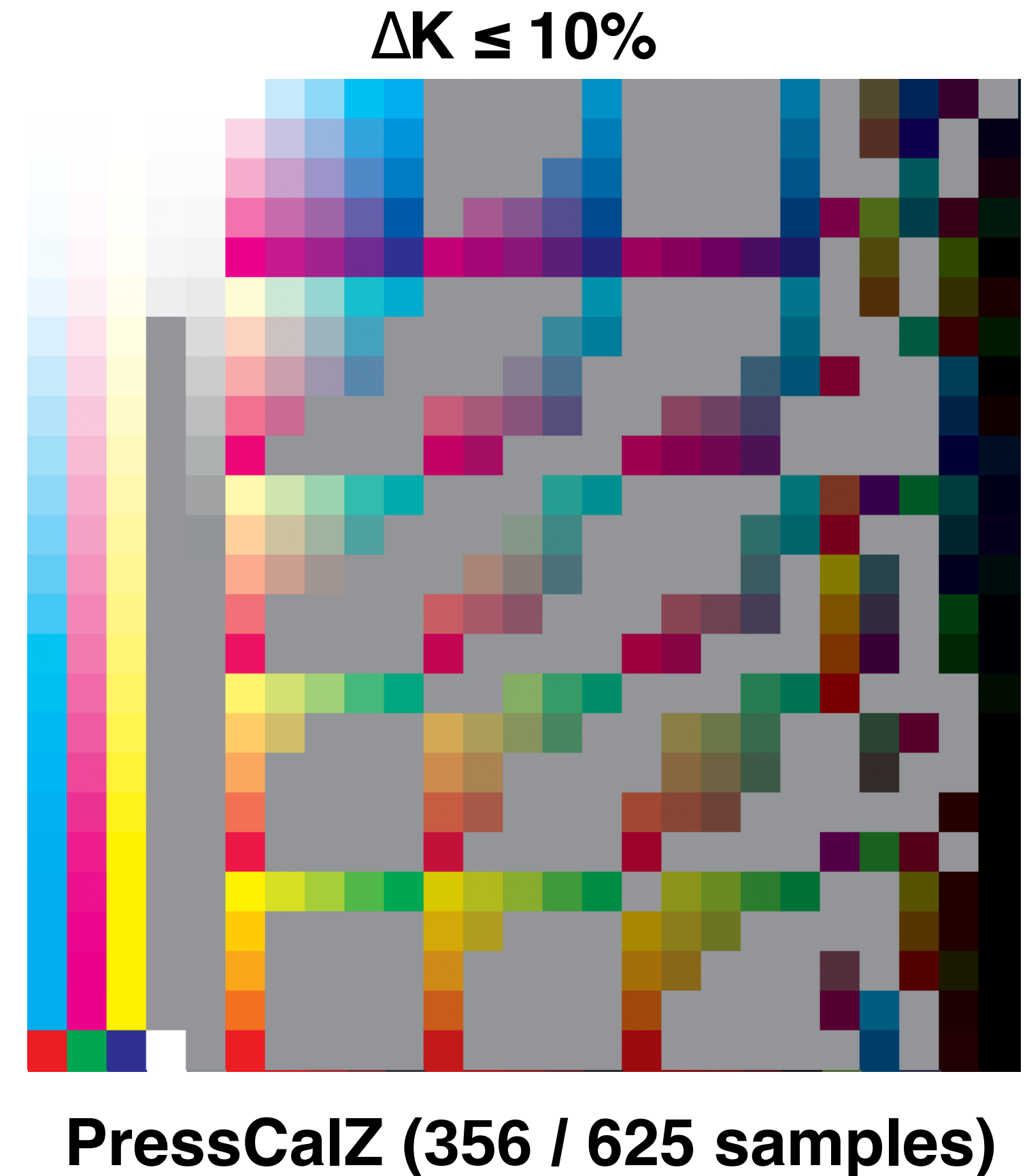
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 - Any number of samples
 - Any CMYK color mixtures



PressCalZ (625 samples)

Sample Sets

- **OPTIMAL** method is flexible
 - Any number of samples
 - Any CMYK color mixtures
- Sample **Selection**
 - Select colors likely to be printed
 - **Round-Trip** (using color profile)
 - Select colors with $\Delta K \leq 10\%$
 - Accounts for profile UCR/GCR



Demonstration

Press: Heidelberg 105XL

Paper: Endurance Silk (Veritiv)

Ink: Toyo Hyplus

Plates: Agfa Energy Elite Pro
(Positive-Working, Thermal, Linear)

Screening: Agfa Sublima 240 lpi XM
(Cross-Modulated) Hybrid (AM/FM)

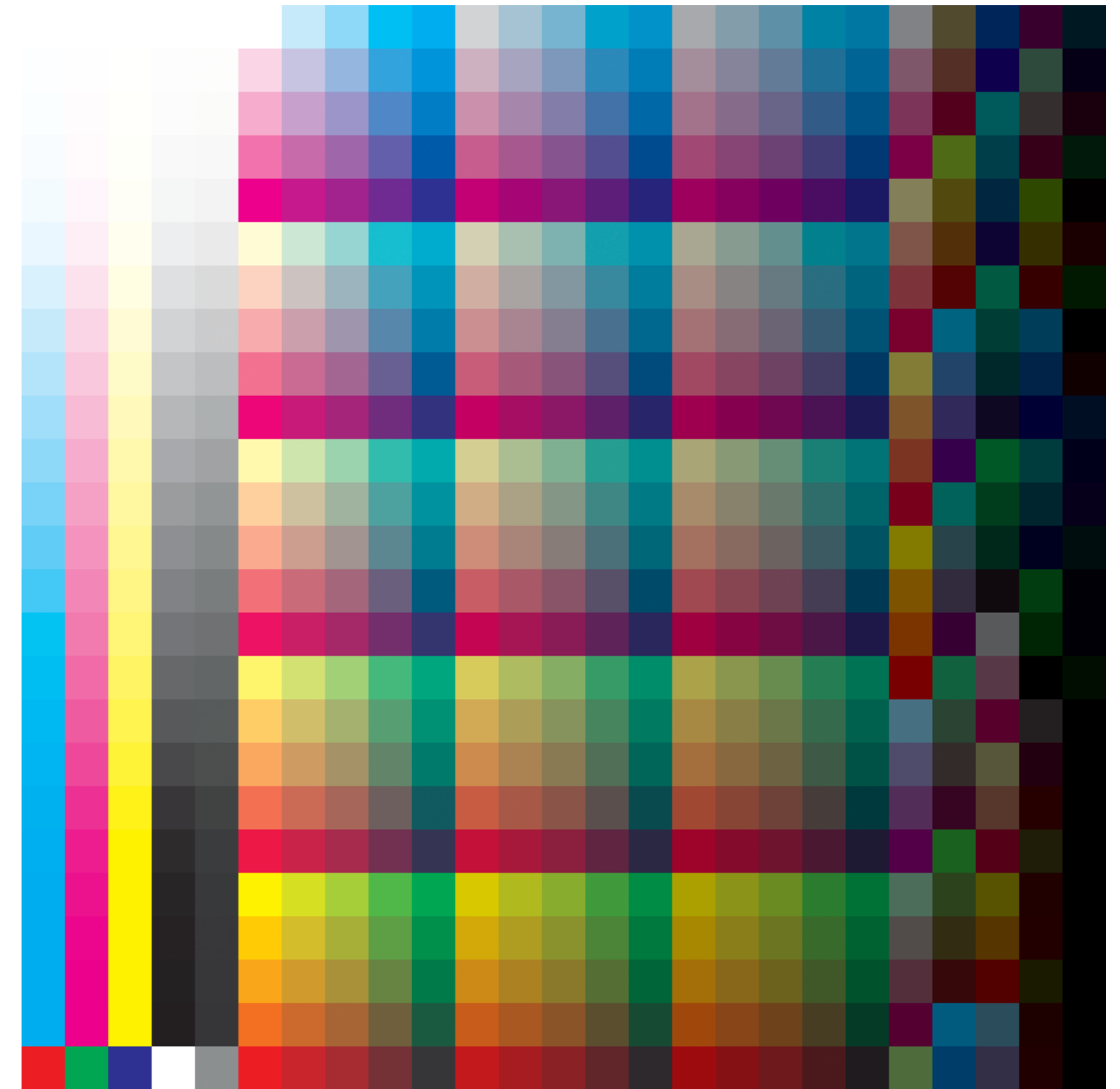
Test Chart: PressCalZ

Instrument: X-Rite i1Pro 2 / i1iO

Measurements: Spectral – M0, M1, M2

Data Sets: 10 (5 sheets x 2 charts)

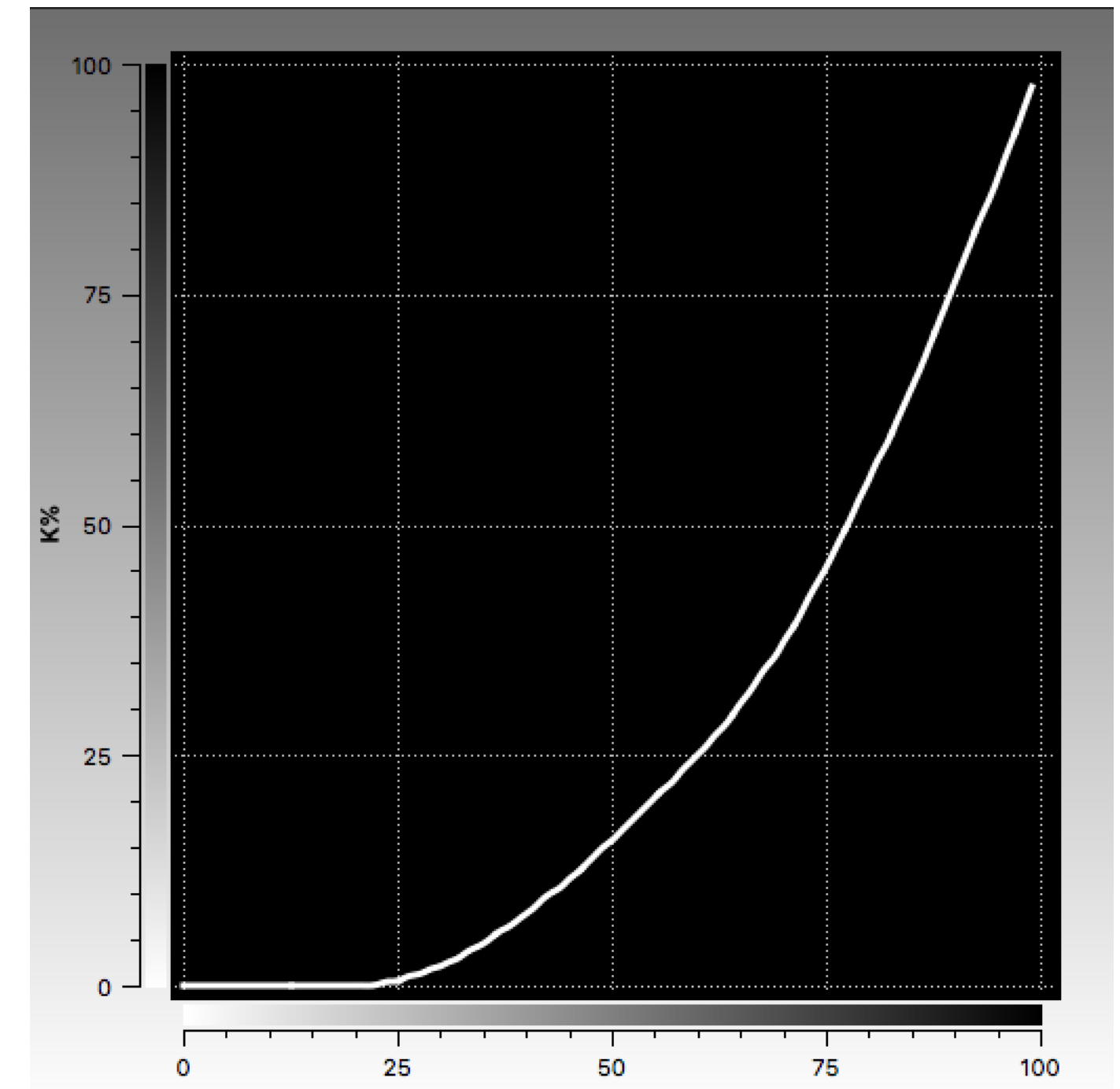
Date: July 28, 2017



PressCalZ (625 samples)

Demonstration

Reference Data: CGATS21-2-CRPC6.txt
Source: ANSI CGATS Standards Committee
Reference Profile: GRACoL2013_CRPC6.icc
Source: Idealliance
Software: X-Rite i1Profiler
Black Start: 20%
Black Curve: heavy
Total Ink: 320%



Black Curve

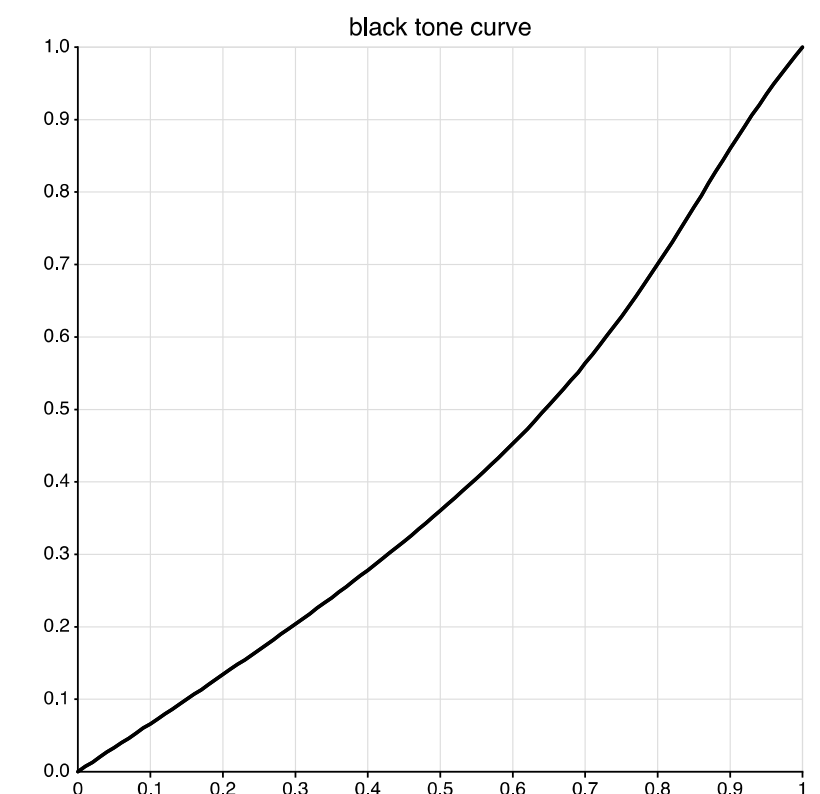
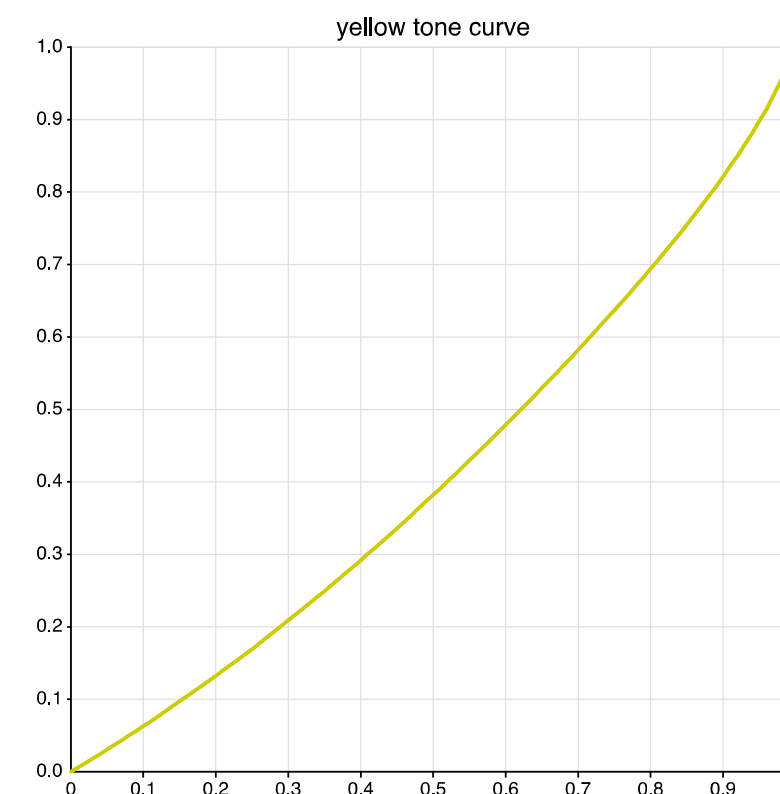
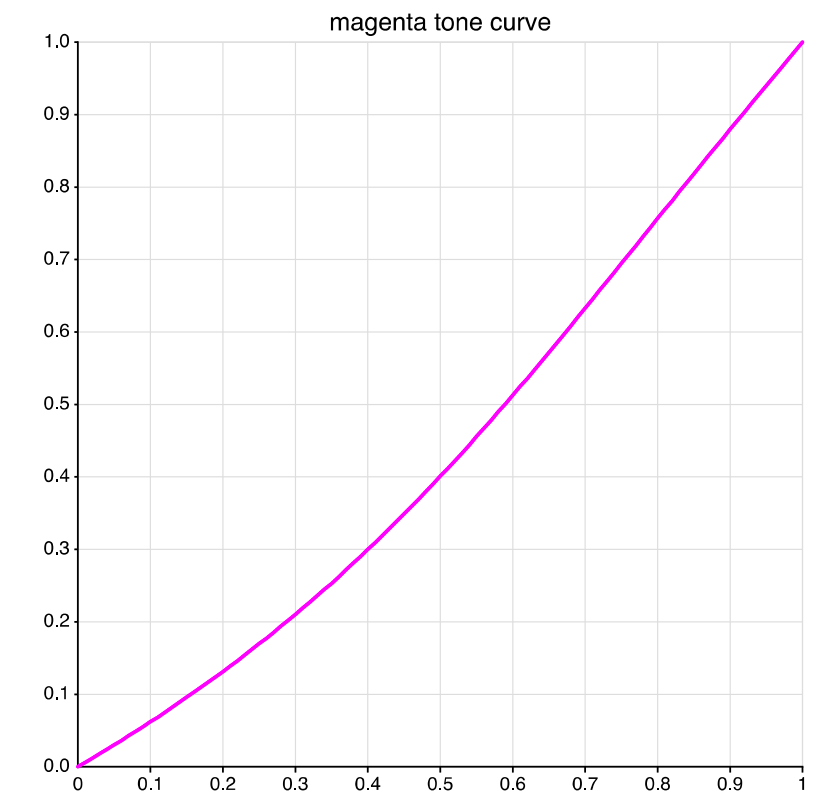
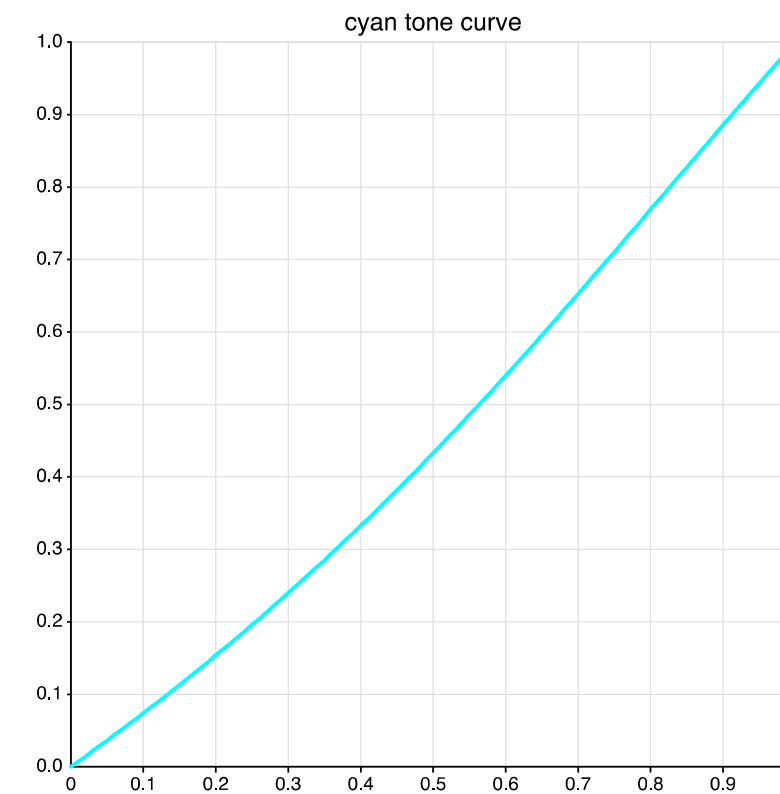
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We developed the **OPTIMAL** method using our **color tool kit**. The color tool kit is a set of Perl modules that implement many color management functions. There is no GUI. We run the software from a text editor.

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First, we will show you **how curves are created**. Then, we will simulate a press run using color management, to show **how well the curves perform**.



Advantages

- **Targets the proofing reference profile/data set**
(e.g. GRACoL2013, FOGRA 51)
- **Flexible**
 - Any printing process
 - Any number of inks
 - Any gray balance
 - Any sample set
 - Any error metric
 - Adjustable curve complexity
- **Powerful**
 - Samples may contain any mixture of inks
 - Accounts for the effects of UCR/GCR
 - Accounts for ink trapping variations (including black ink)
 - Makes curves for multiple references with a single test run

Advantages

- **Robust**
 - Reliable (no surprises or failures, with a well-chosen sample set)
 - Smooths process and measurement variations
 - Small impact from bad or missing sample measurements
 - Outliers may be identified and removed
- **Easy to learn and use**
- **Uses standard mathematical techniques**
- **Open source software implementation available**
- **Free (no patents, royalties, training fees, or certification fees)**

Questions?

Some possible topics...

- Bernstein polynomials
- Optimization
- Sample sets
- Flowchart
- Reference data sets
- Black generation
- N-channel curves (CMYKOGV, CMYK + spot, etc.)
- Gray balance
- TRAND (G7)
- Colorimetric tone value (CTV)
- Software
- Open source

Conclusion

- Read the TAGA paper for more details
- **Open source** software available on request
- **CONTACTS**
William (Bill) Birkett wbirkett@doplganger.com
Charles (Chuck) Spontelli csponte@bgsu.edu