International Circle of Educational Institutes for Graphic Arts Technology and Management (IC)

School of Media Sciences

R·I·T | College of Imaging Arts and Sciences

CROSS-MEDIA INNOVATION CENTER at RIT

WHAT I LEARNED FROM RESEARCHING PRINTING UNIFORMITY APART FROM BETTER UNDERSTANDING OF UNIFORMITY

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TORONTO | JUNE 2013 | RYERSON UNIVERSITY

Agenda

- Talk about my thesis
- Talk about the evolution of my thesis project
- Demonstrate some visualizations

About Myself!

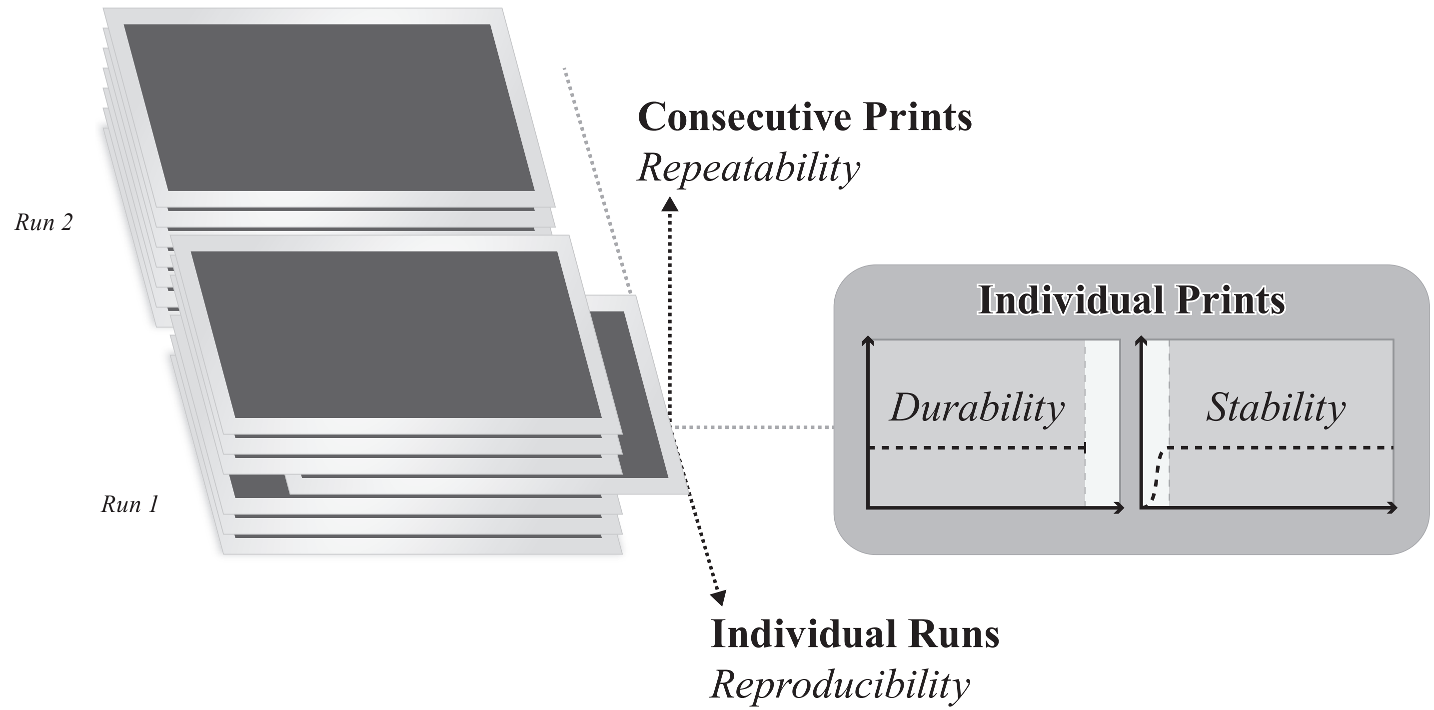
- M. Sc. Print Media
  Rochester Institute of Technology, 2013 (est.)
- B. Tech. Graphic Communications Management
  Ryerson University, 2009
- Knowledge Areas:
  - Quality Control in Printing & Statistical Analysis
  - Software Development, Engineering
  - Graphic Design & Web Development
  - Entrepreneurship & Management

Thesis Overview

- Working together with Franz Sigg
- Objectives:
  - Practical ways to characterize and measure Printing Uniformity
  - Realistic impact of Printing Uniformity on standards & quality
- Outcomes:
  - Measurement Method
  - Visualization Toolkit
  - Conceptual Framework
  - Quantitative Models

Printing Uniformity

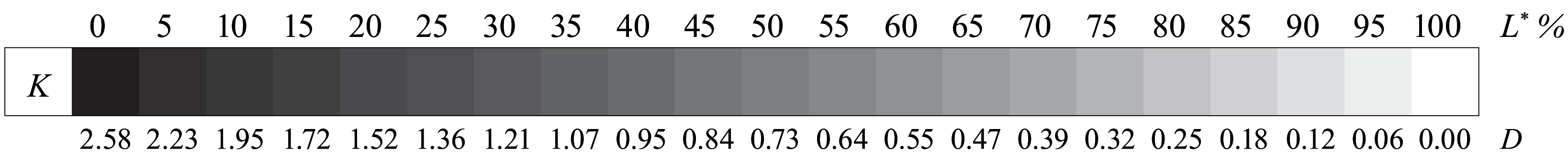
- Spatial & Temporal Uniform of Printing Density*



Temporal dimensions of printing relative to the reproduction process versus a printed product

Printing Density*

- Some measure of optical density (L* or Density)

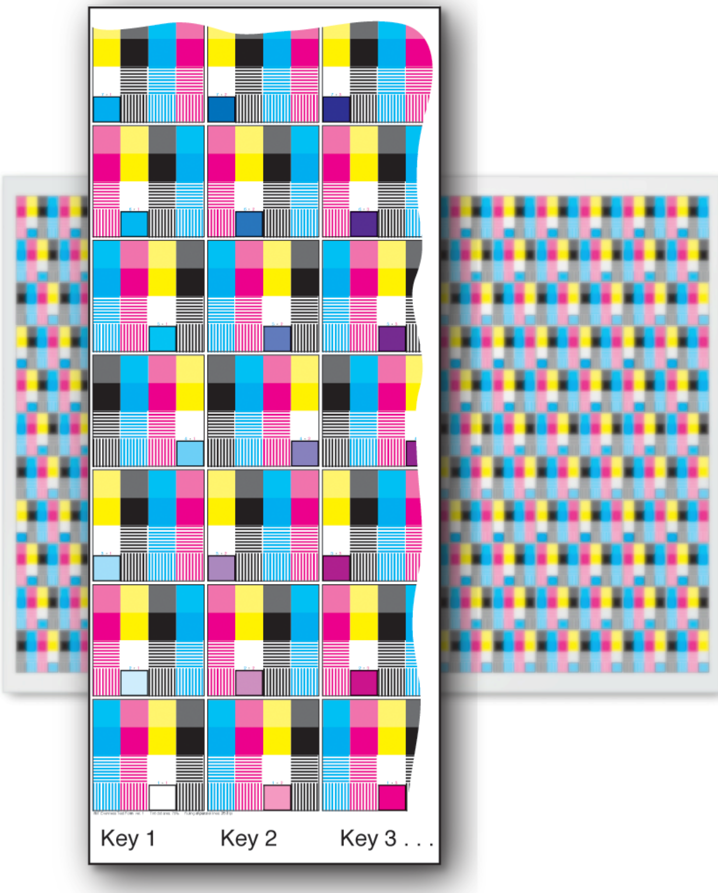


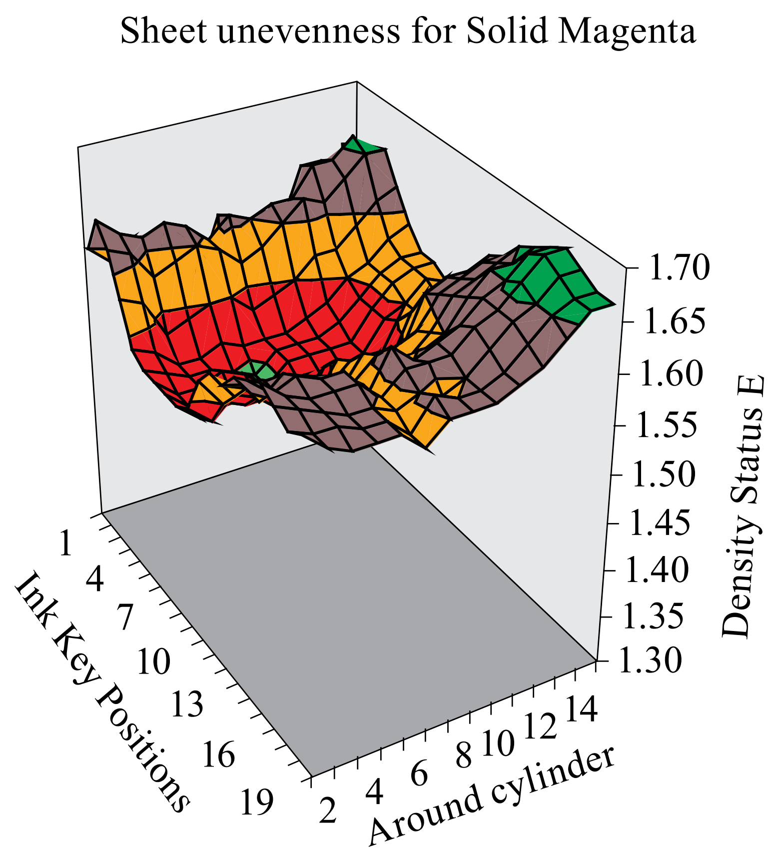
* None-explicit measure of printing density like L* or Visual Density

Stage #1

Gateway Works

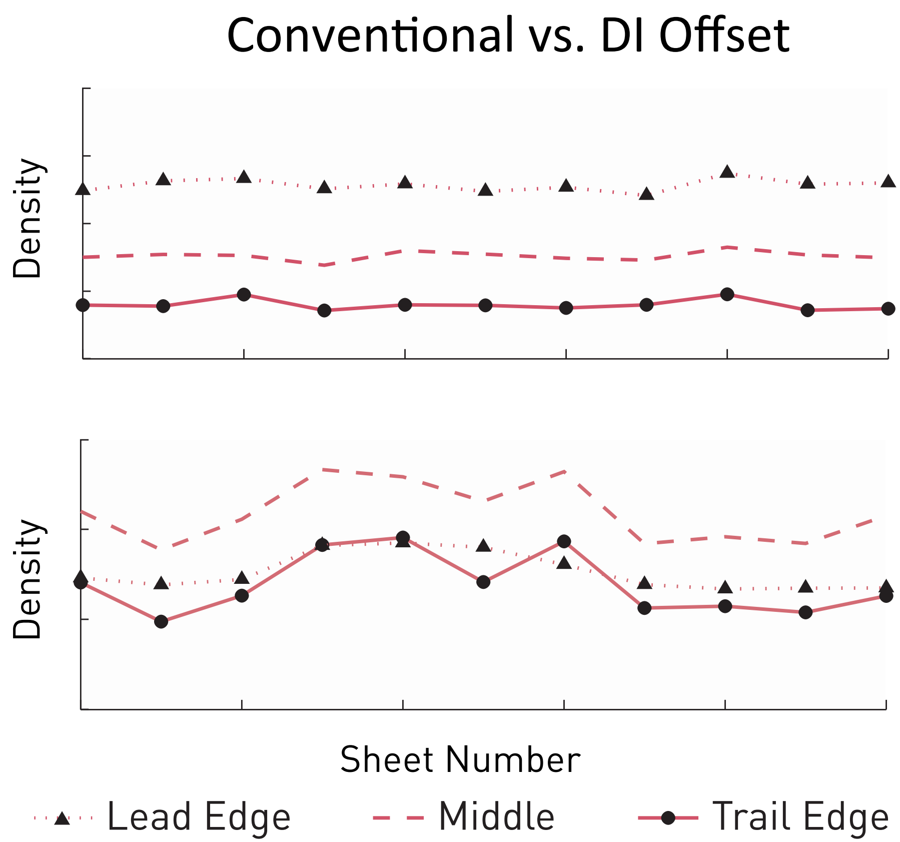
Work by Sigg

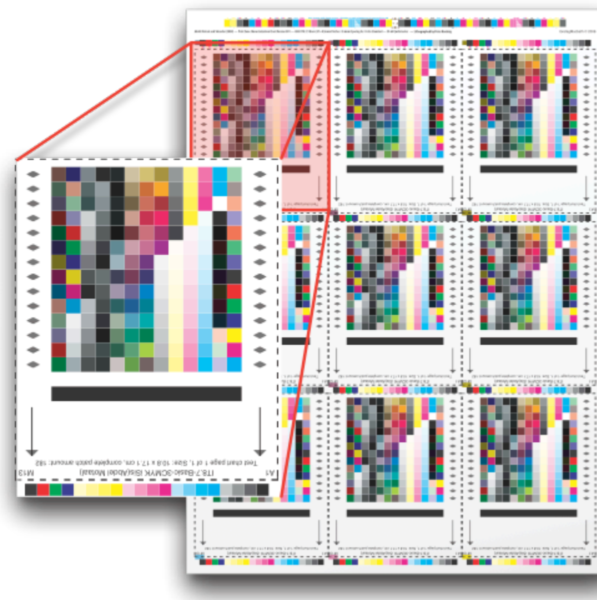




Adapted from Spatial Uniformity by Sigg (TAGA Proceedings, 2007)

Work by Abdel Motaal & Sikander





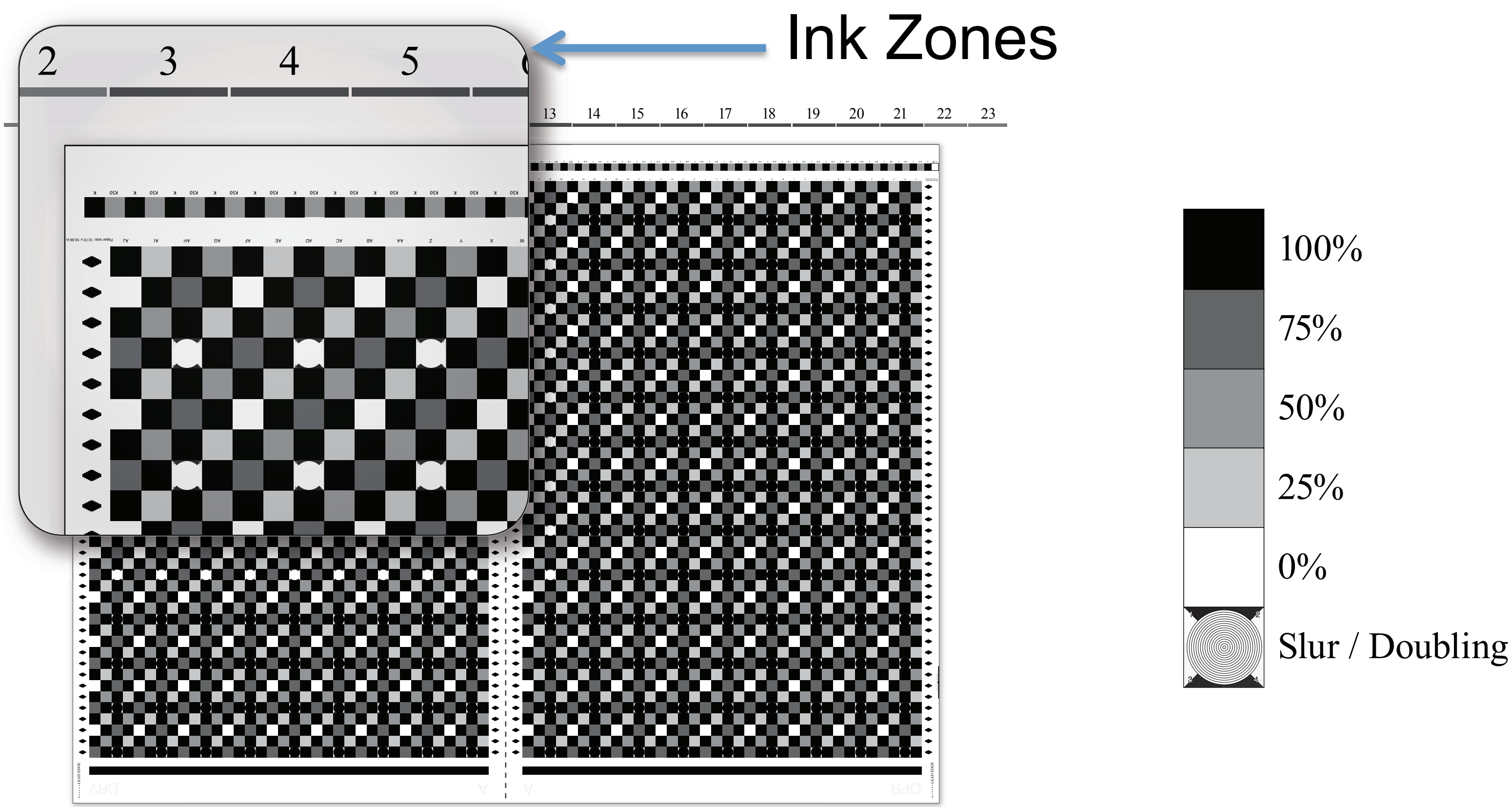
Adapted from Repeatability in Lithography by A. Motaal & Sikander (TAGA Proceedings, 2009)

Revelation #1

Separation of Concerns!

(it is sometimes better to see things black and white)

Data Collection



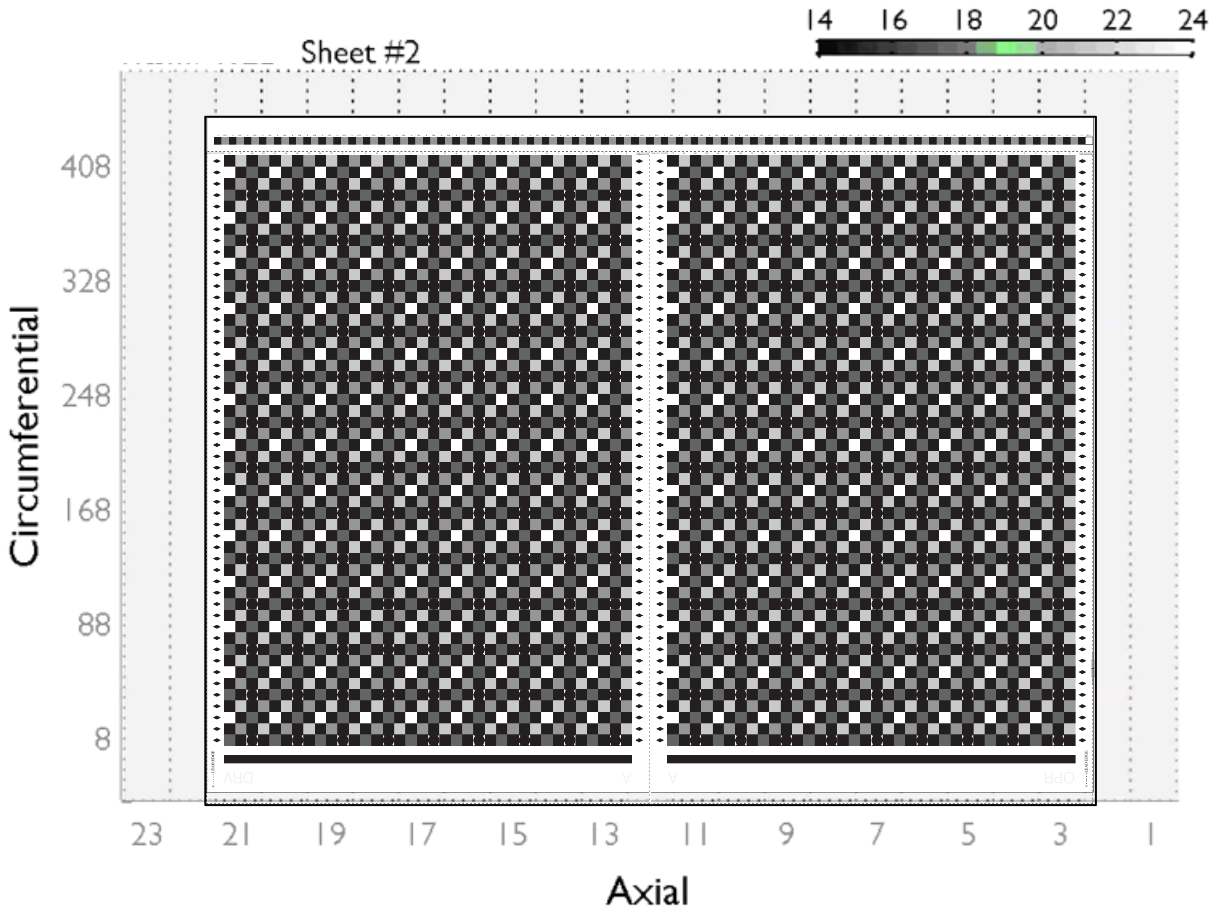
New test form designed by Abdel Motaal & Sigg for single-color uniformity

Franz Sigg wrote a PostScript program customizable to fit different press format

Stage #2

Data Visualization

2D Visualization of Landscape Press



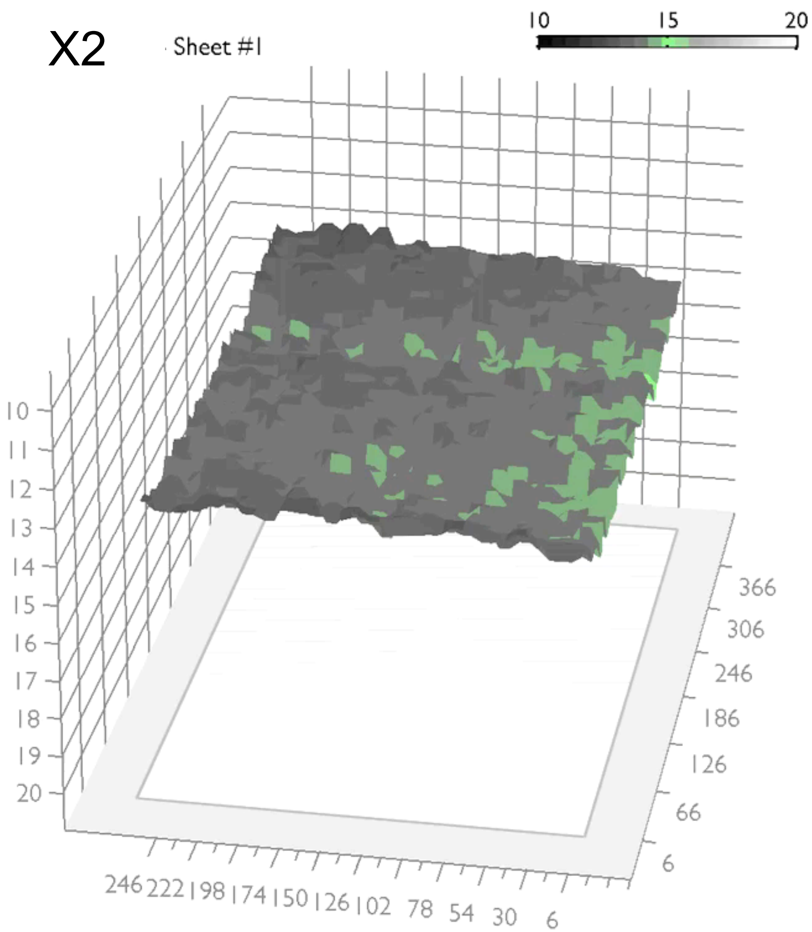
L* for solid patches for a single unit on a conventional offset press

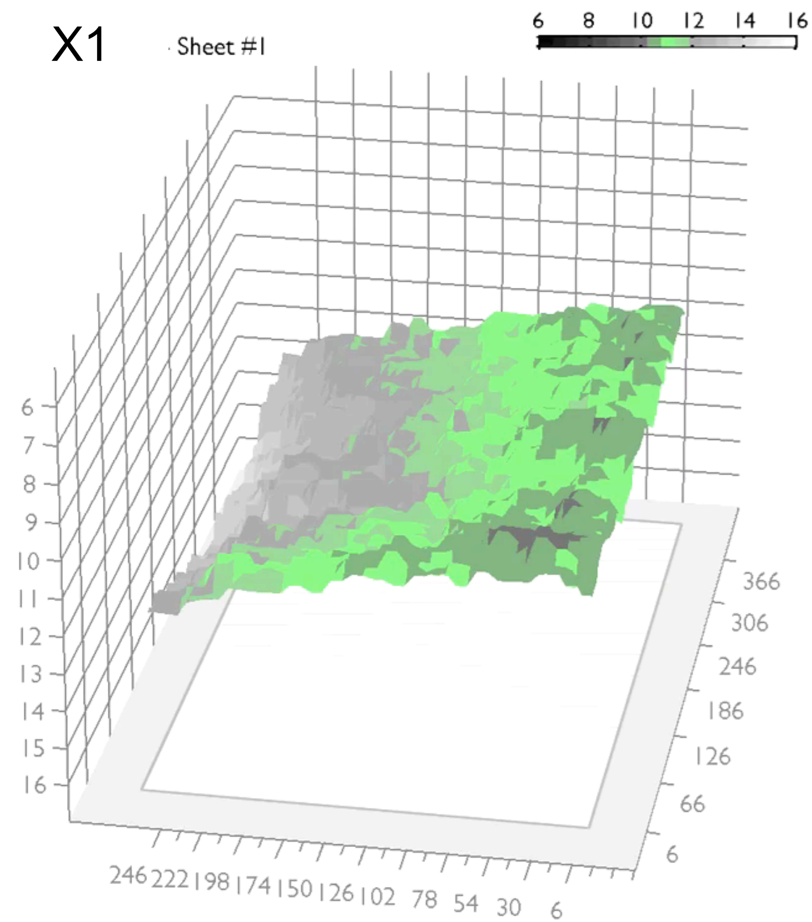
Revelation #2

Visualizations don't work as well on paper!

(at least not when writing the results chapter)

3D Visualization of Portrait Presses



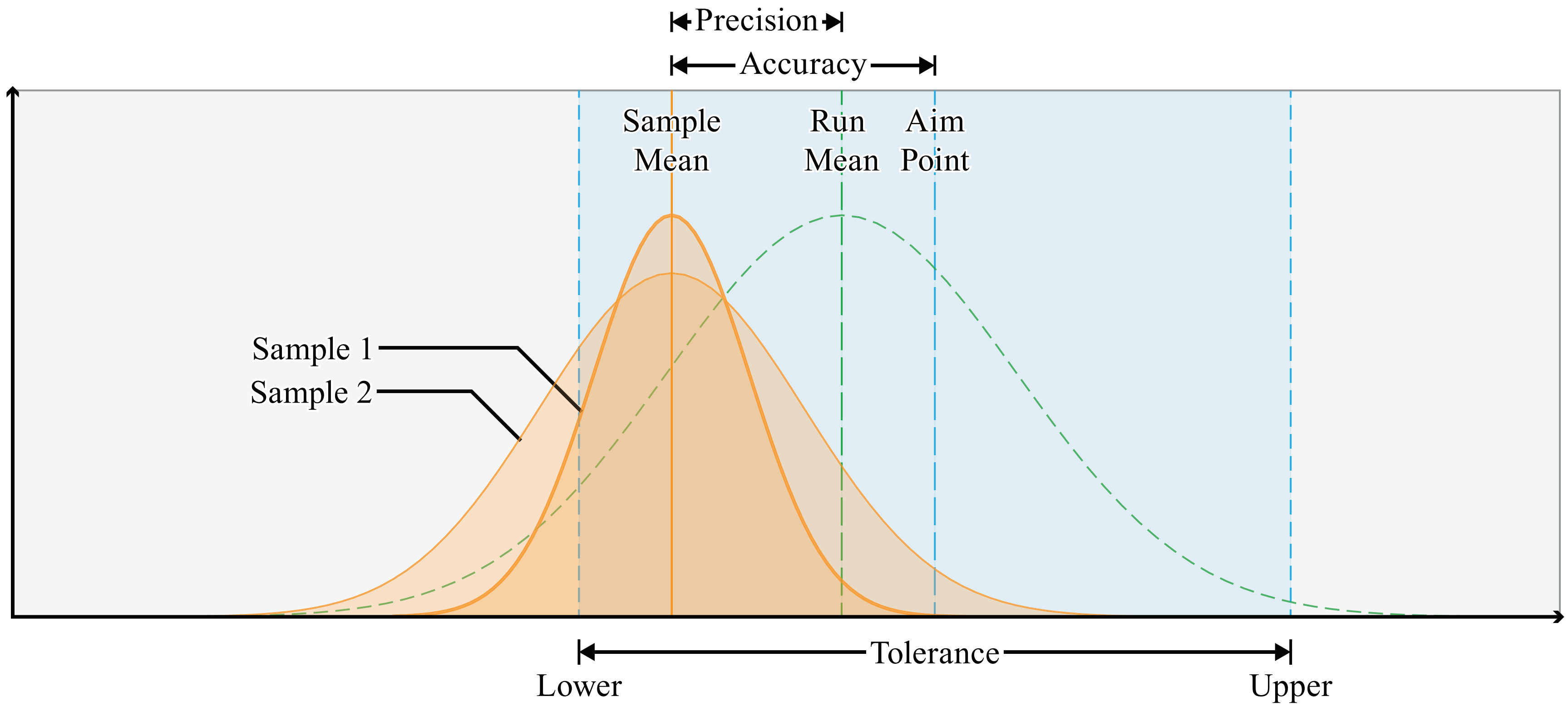


L* for solid patches for two identical-size press models from same vendor (xerography)

Stage #3

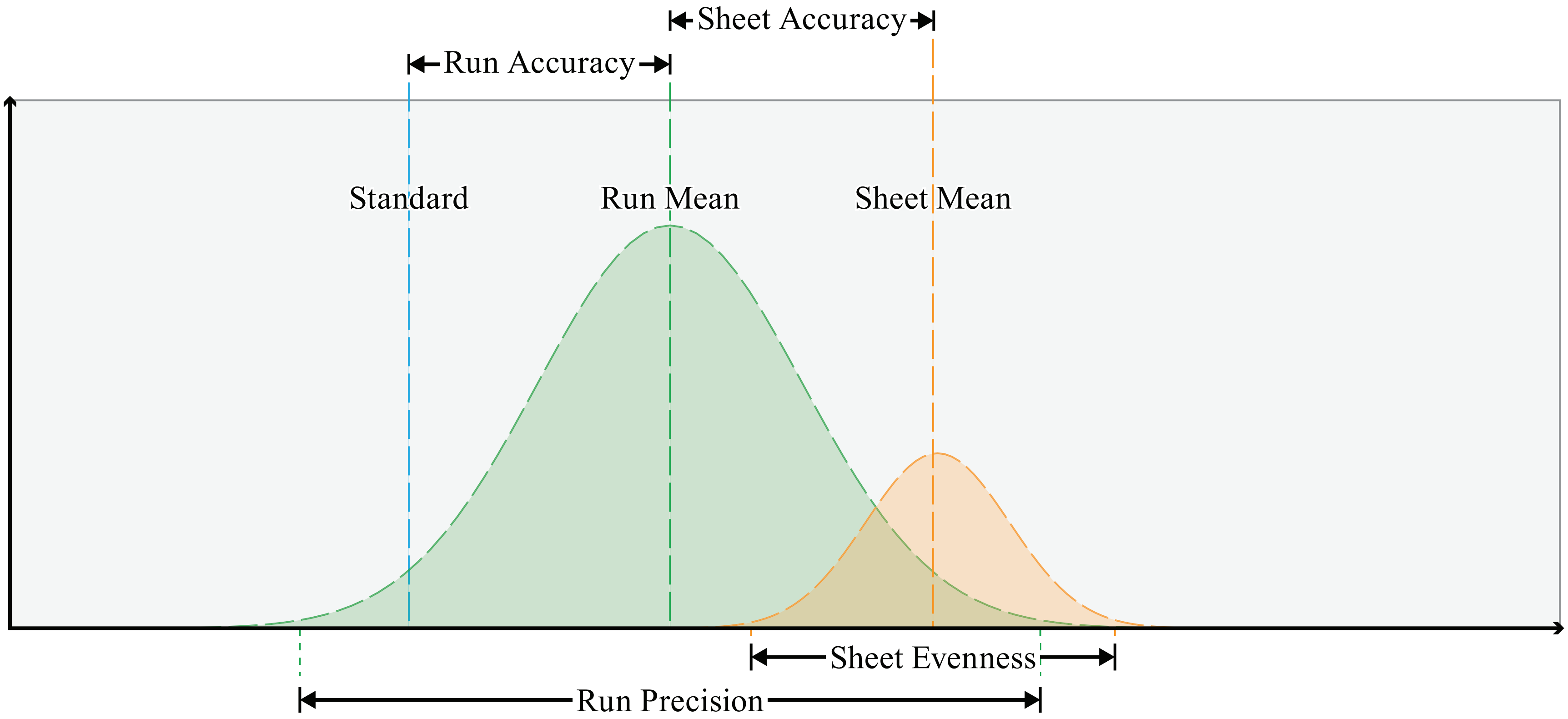
Descriptive Statistics

Statistical Approach



Adapted from Accuracy and Precision by Siljander & Fisch (TAGA Proceedings, 2001)

Statistical Approach



* Precision includes both spatial evenness & temporal repeatability

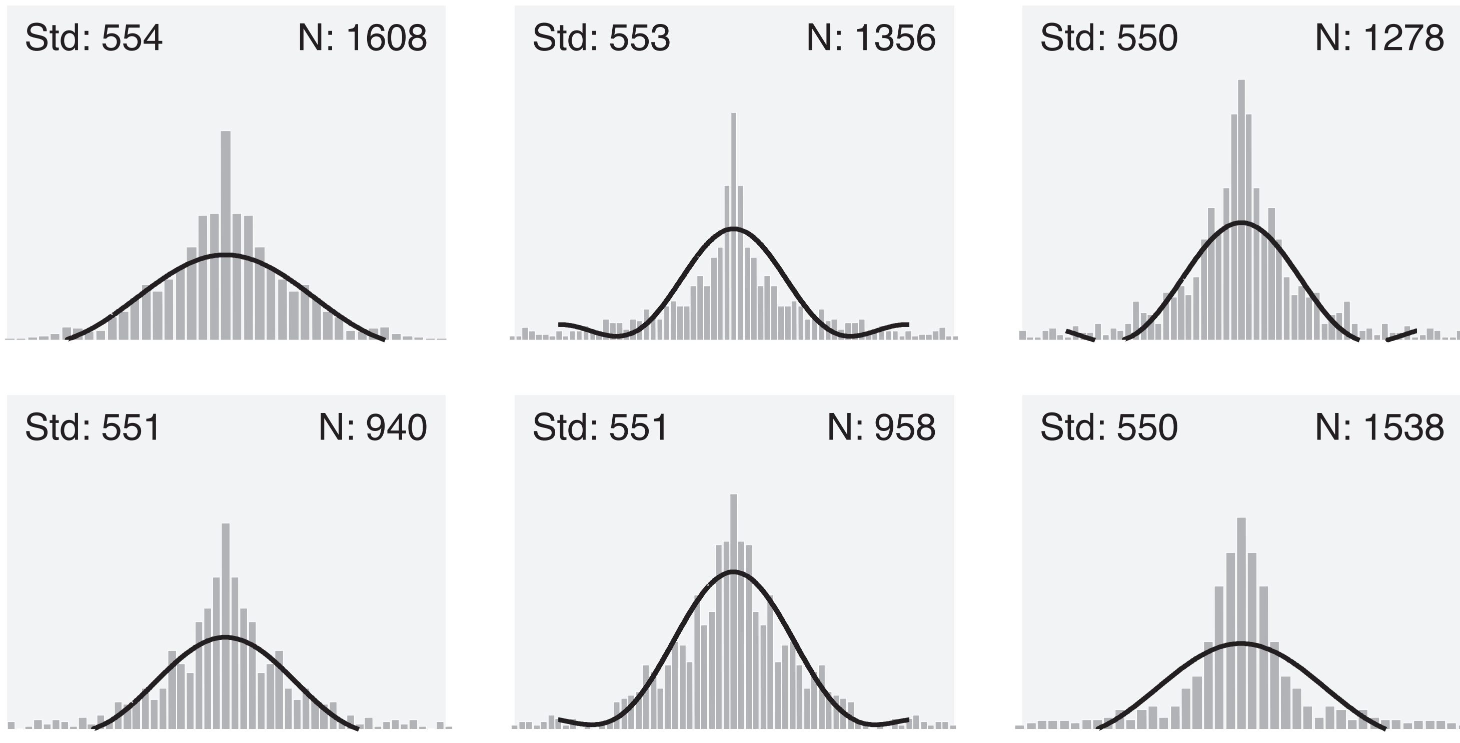
Adapted from Accuracy and Precision by Siljander & Fisch (TAGA Proceedings, 2001)

Revelation #3

Sigma doesn't work well on it's own!

(especially when describing complex spatial-temporal trends)

Statistical Odds!

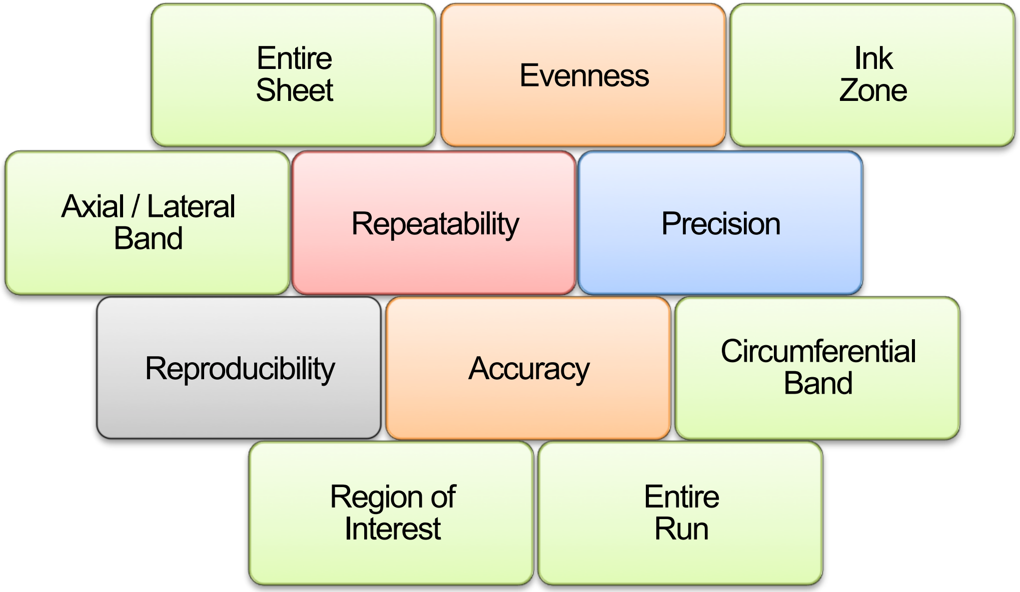


35 random theoretical data-sets with same mean and comparably consistent standard deviation

Stage #4

Back to the Drawing Board

Theoretical Paradigm



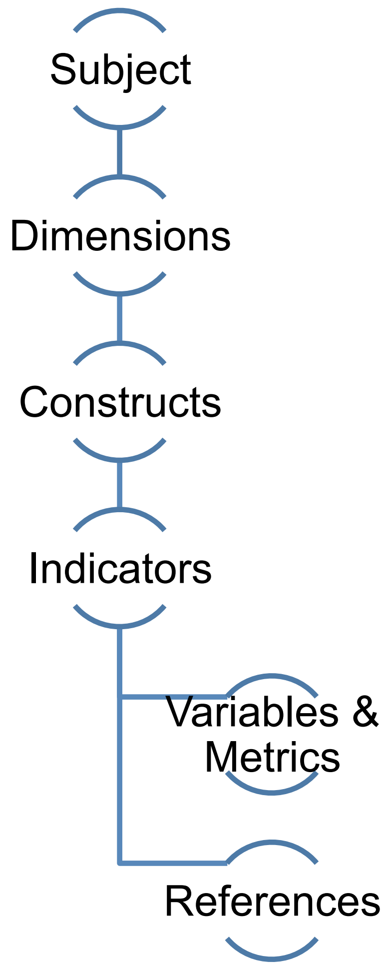
Inspired by Building a Conceptual Framework by Jabareen (International Journal of Qualitative Methods, 2009)

Revelation #4

Clearing up concepts is critical!

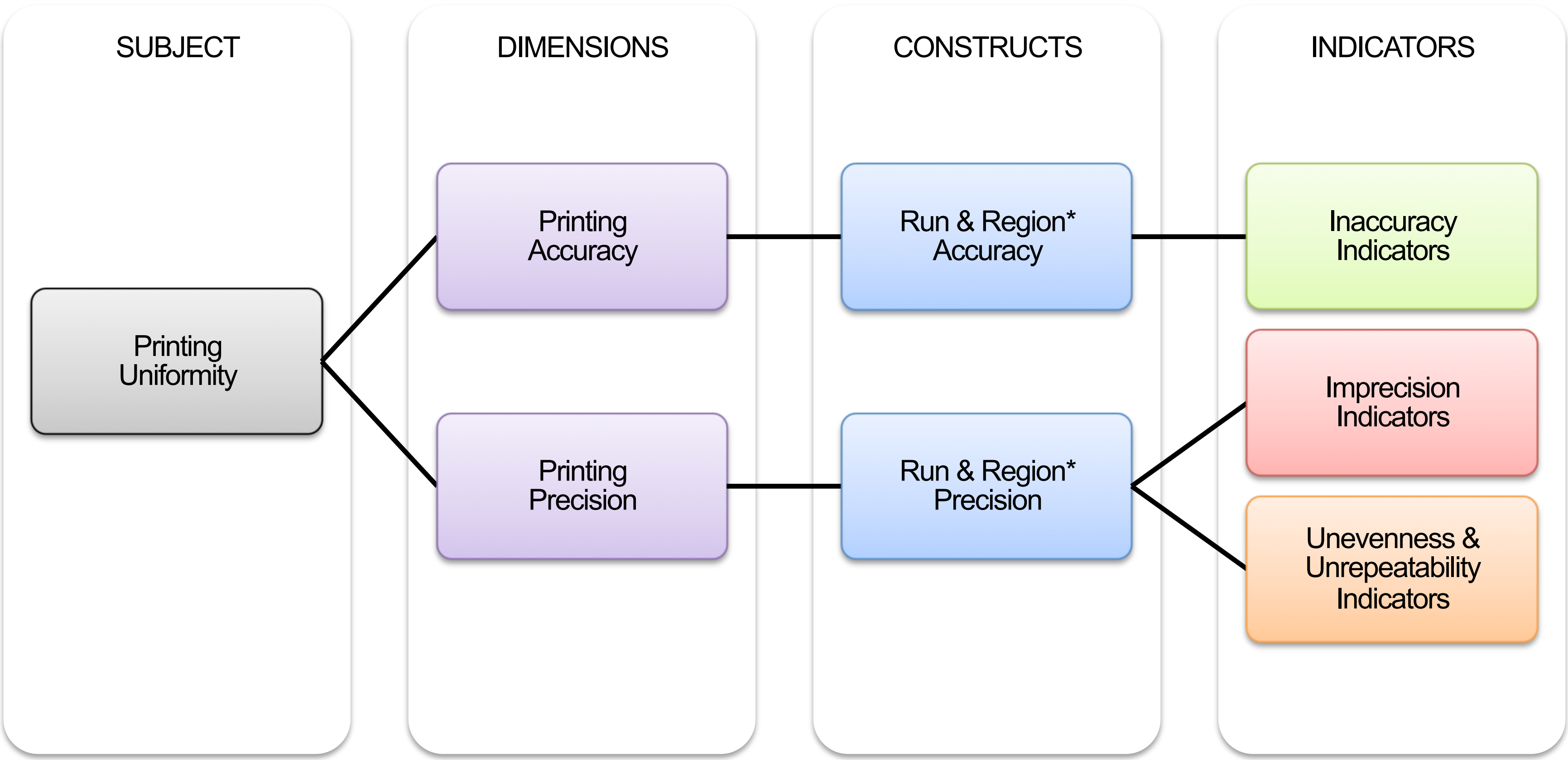
(metrics are worthless without clarity of context and meaning)

Conceptual Order



Inspired from Building a Conceptual Framework by Jabareen (International Journal of Qualitative Methods, 2009)

Conceptual Framework



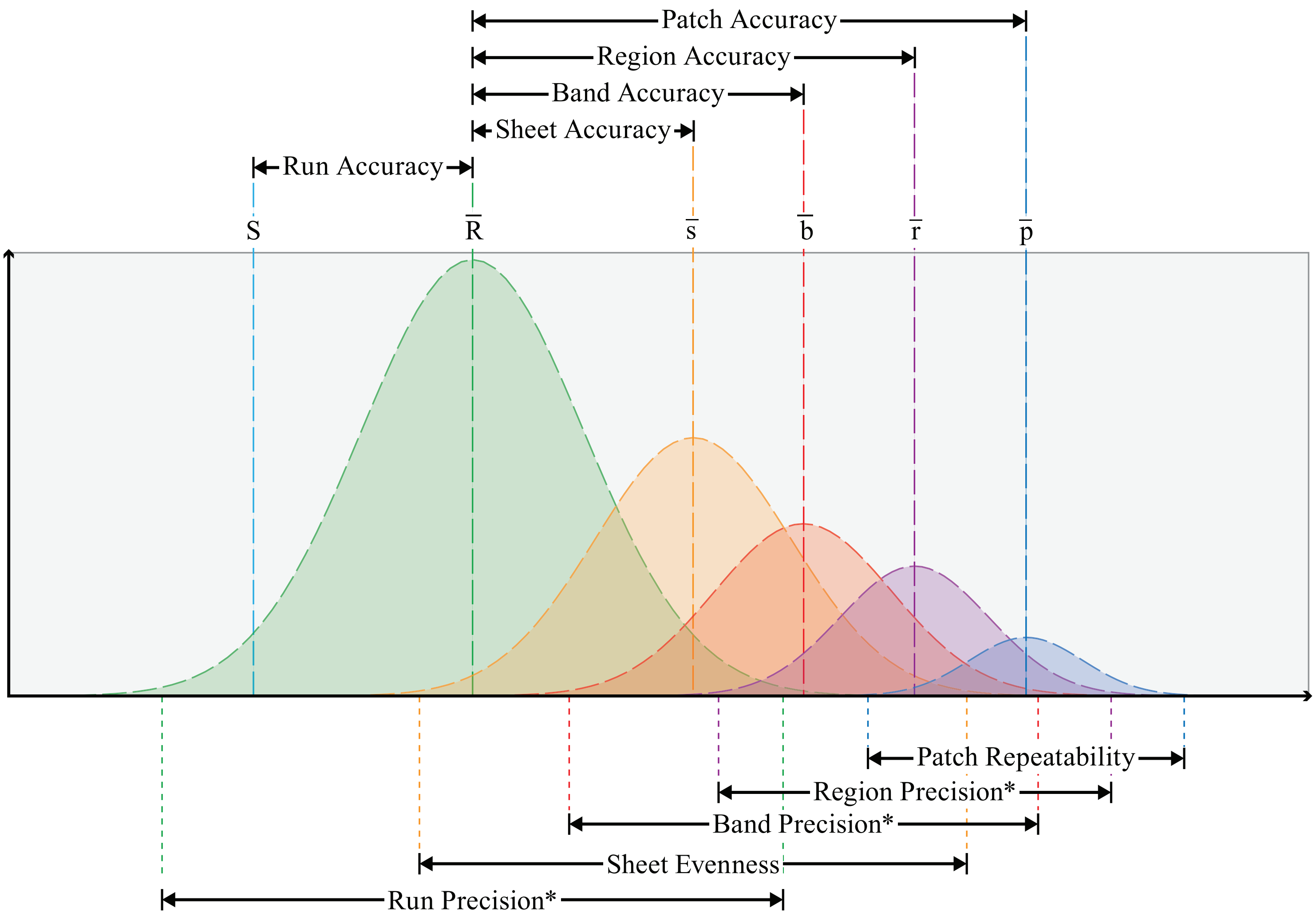
There is no right and wrong answers but infinite ways to put order into chaos!

There is always room for rethinking and hard to avoid making improvements that make sense.

Stage #5

Working the Numbers

The Practical Approach



Inspired by Jabareen, Siljander & Fisch

*

Revelation #5

Models can easily compliment indicators!

(don’t try to fit models to phenomena… fit models to quantifiable concepts)

Inaccuracy Score

- Inaccuracy Scores
  - Extent of run or region* inaccuracy relative to defined tolerance

$$\text{Inaccuracy Value} = \left(\frac{1}{n} \times \sum_{i=1}^{n} z_i \right) - \bar{Z}$$

z_i	is a density value from the set or a subset of values
n	is the size of the set or subset of density values
$\bar{Z}$	is the standard or the mean of the entrie set of density values

$$\text{Inaccuracy Score} = \left| \frac{\text{Inaccuracy Value}}{\frac{1}{2} \times \text{Tolerance}} \right|$$

Example: For the specification 1.7±0.5, the standard is 1.7 and the tolerance is 1.0. Run inaccuracy value is the difference between the standard and the mean of the entire run. Region inaccuracy value is the difference between the run mean and the mean of the patches in a given region of interest.

Imprecision Score

- Imprecision Scores
  - Extent of run or region* imprecision relative to defined tolerance

$$\text{Imprecision Value} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(z_i - \overline{z}\right)^2}$$

z_i	is a density value from the set or a subset of values
n	is the size of the set or subset of density values
$\overline{z}$	is the mean of the entrie set or the subset of density values

$$\text{Imprecision Score} = \frac{6 \times \text{Imprecision Value}}{\text{Tolerance}}$$

Example: For the specification 1.7±0.5, the tolerance is 1.0. Run imprecision value is the standard deviation for the entire run. Region imprecision value is the standard deviation for the patches in a given region.

Inaccuracy Run Directionality

- Inaccuracy Directionality
  - Extent of run variability along either direction vs. the other

$$\text{Inaccuracy Directionality} = \frac{x_{max} - x_{min}}{r_{max} - r_{min}}$$

x_{max}	is the maximum inaccuracy value for the axial or cirumferential bands
x_{min}	is the minimum inaccuracy value for the axial or cirumferential bands
r_{max}	is the maximum inaccuracy value for the regions
r_{min}	is the minimum inaccuracy value for the regions

Example: For a 5x3 category landscape press the circumferential and axial inaccuracy directionalities are the range of inaccuracy value for the bands relative to the range of inaccuracy values for the regions. The assumption is that the range for regions represents the sum of inaccuracy for both dimensions. Pattern visibility is dependent on the ranges for regions and bands. A higher directionality for either dimensions indicates higher pattern alignment in that direction. If both directionalities are equal, the pattern is equally equally aligned (45º) or there is no visible pattern.

Imprecision Run Directionality

- Imprecision Directionality
  - Extent of run variability along either direction vs. the other

$$\text{Imprecision Directionality} = \frac{\frac{1}{n} \times \sum_{i=1}^{n} x_i^2}{\frac{1}{n} \times \sum_{i=1}^{n} x_i^2 + \frac{1}{n'} \times \sum_{j=1}^{n'} y_j^2}$$

x_i	is an imprecision value of the set of axial or cirumferential bands
y_j	is an imprecision value of the opposite set of bands
n	is the number of axial or circumferential bands
n'	is the number of opposite bands

Example: For a 5x3 category landscape press the circumferential and axial imprecision directionalities are the mean of variance for the bands in each direction relative to the sum of the mean of variance for both directions. Pattern visibility is dependent on imprecision values. A higher directionality for either dimensions indicates higher pattern alignment in that direction. If both directionalities are equal, the pattern is equally equally aligned (45º) or there is no visible pattern.

Inaccuracy Region Proportions

- Inaccuracy Proportions
  - Extent of region* variability vs. variability in all regions

$$\text{Inaccuracy Proportion} = \frac{x_i}{\sum_{j=1}^{n} x_j}$$

x_i is the inaccuracy within the region of interest

x_j is the inaccuracy within each exclusive region in the set

n is the number of exlusive regions in the set

Example: Ex: For a 5x3 category landscape press there are 15 regions resulting for 5 axial and 3 circumferential bands. Each region's inaccuracy proportion is relative to the sum of all inaccuracy values for all regions. Each axial band's inaccuracy proportion is relative to the sum of inaccuracy values across all axial bands. Each circumferential band's inaccuracy proportion is relative to the sum of the inaccuracy values along all circumferential bands. If the press has ink zones, each zone's inaccuracy proportion would be relative to sum of inaccuracy values for all zones.

Imprecision Region Proportions

- Imprecision Proportions
  - Extent of region* variability vs. variability in all regions

$$\text{Imprecision Proportion} = \frac{x_i^2}{\sum_{j=1}^{n} x_j^2}$$

x_i is the imprecision, unevenness or unrepeatability within the region of interest

x_j is the imprecision, unevenness or unrepeatability for some region in the set

n is the number of exlusive regions in the set

Example: For a 5x3 category landscape press there are 15 regions resulting for 5 axial and 3 circumferential bands. Each region's imprecision proportion is relative to the sum of all imprecision values for all regions. Each axial band's imprecision proportion is relative to the sum of all imprecision values across all axial bands. Each circumferential band's imprecision proportion is relative to the sum of imprecision values along all circumferential bands. If the press has ink zones, each zone's imprecision proportion would be relative to the sum of imprecision values for all zones.

Run & Region Components of Imprecision

- Unevenness & Unrepeatability Values
  - Run or region* variability within and between sheets

$$\text{Unevenness Value} = \sqrt{\frac{1}{\hat{n}} \times \sum_{i=1}^{\hat{n}} k_i^2}$$

k_i is the within-sheet imprecision value for all patches in the sheet or region

$\hat{n}$ is the size of the set of sheets

Ex:

$$\text{Unrepeatability Value} = \sqrt{\frac{1}{\ddot{n}} \times \sum_{j=1}^{\ddot{n}} k_j^2}$$

k_j is the between-sheet imprecision value for all patches in the sheet or region

$\ddot{n}$ is the size of the set of patches in the sheet or region

Example: For any sample of patches in a sample of prints there are unevenness and unrepeatability values. Unevenness value is the mean of variance in each print, which measures sheet evenness based in a sample of sheets. Unrepeatability value is the mean of variance in each patch, which measures patch repeatability in a sample of patches.

Run & Region Imprecision Factors

- Unevenness & Unrepeatability Factor
  - Extent of run or region* variability within vs. between sheets

$$\text{Unevenness Factor} = \frac{\text{Unevenness Value}^2}{\text{Unevenness Value}^2 + \text{Unrepeatability Value}^2}$$

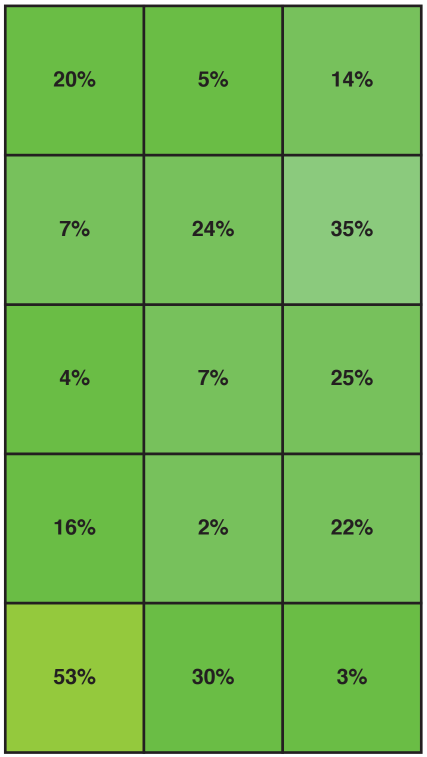
$$\text{Unrepeatability Factor} = \frac{\text{Unrepeatability Value}^2}{\text{Unevenness Value}^2 + \text{Unrepeatability Value}^2}$$

Example: For any sample of patches in a sample of prints there are unevenness and unrepeatability factors. Each factor is derived from its respective value relative to the sum of both unevenness and unrepeatability values.

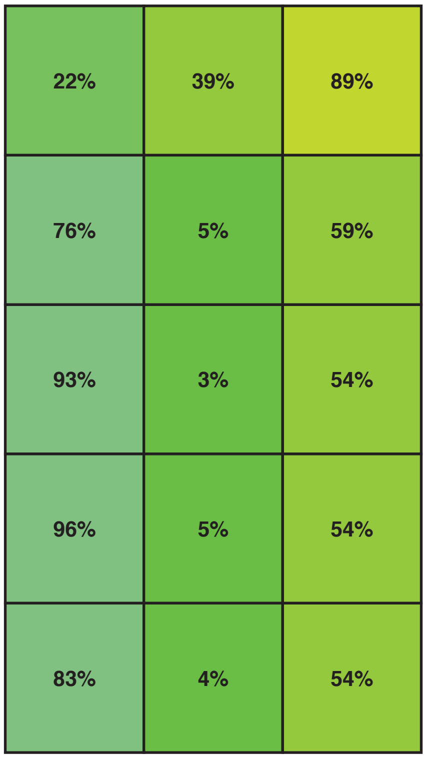
Simple!

Region Inaccuracy Scores

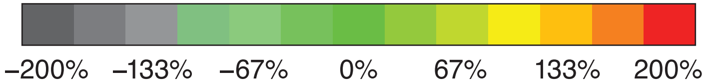
X2 Regions
Inaccuracy Score



X1 Regions
Inaccuracy Score



Sampled area of portrait presses divided into 5 x 3 regions showing inaccuracy trends.



Region Imprecision Scores

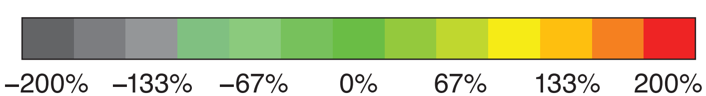
X2 Regions
Imprecision Score

137%	154%	140%
132%	140%	129%
124%	131%	128%
124%	132%	124%
119%	127%	122%

X1 Regions
Imprecision Score

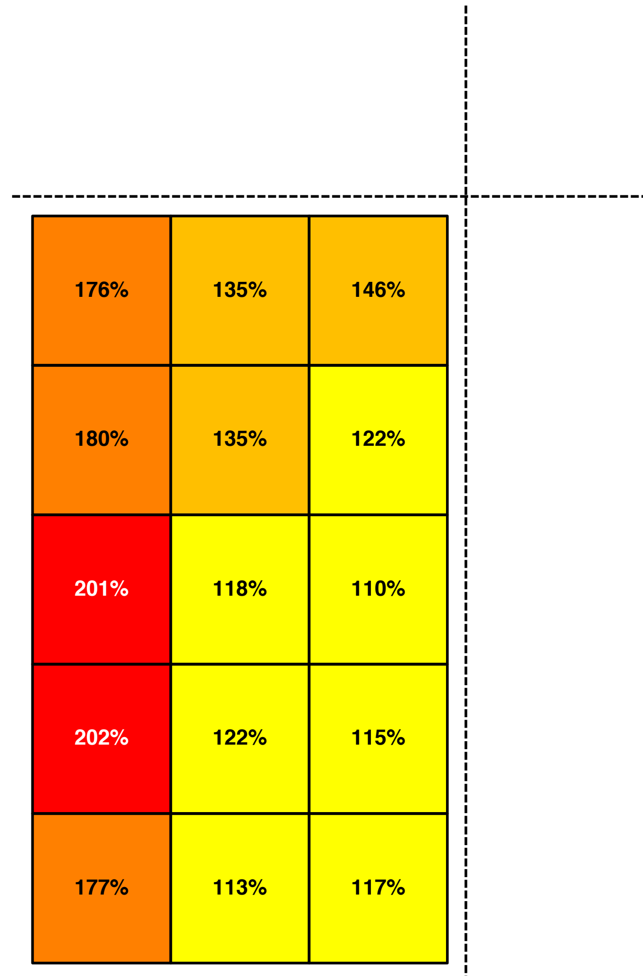
176%	135%	146%
180%	135%	122%
201%	118%	110%
202%	122%	115%
177%	113%	117%

Sampled area of portrait presses divided into 5 x 3 regions showing imprecision trends.

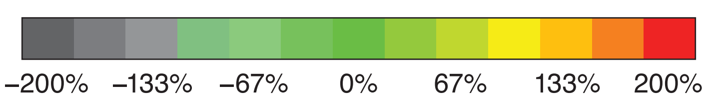


Grid Representation

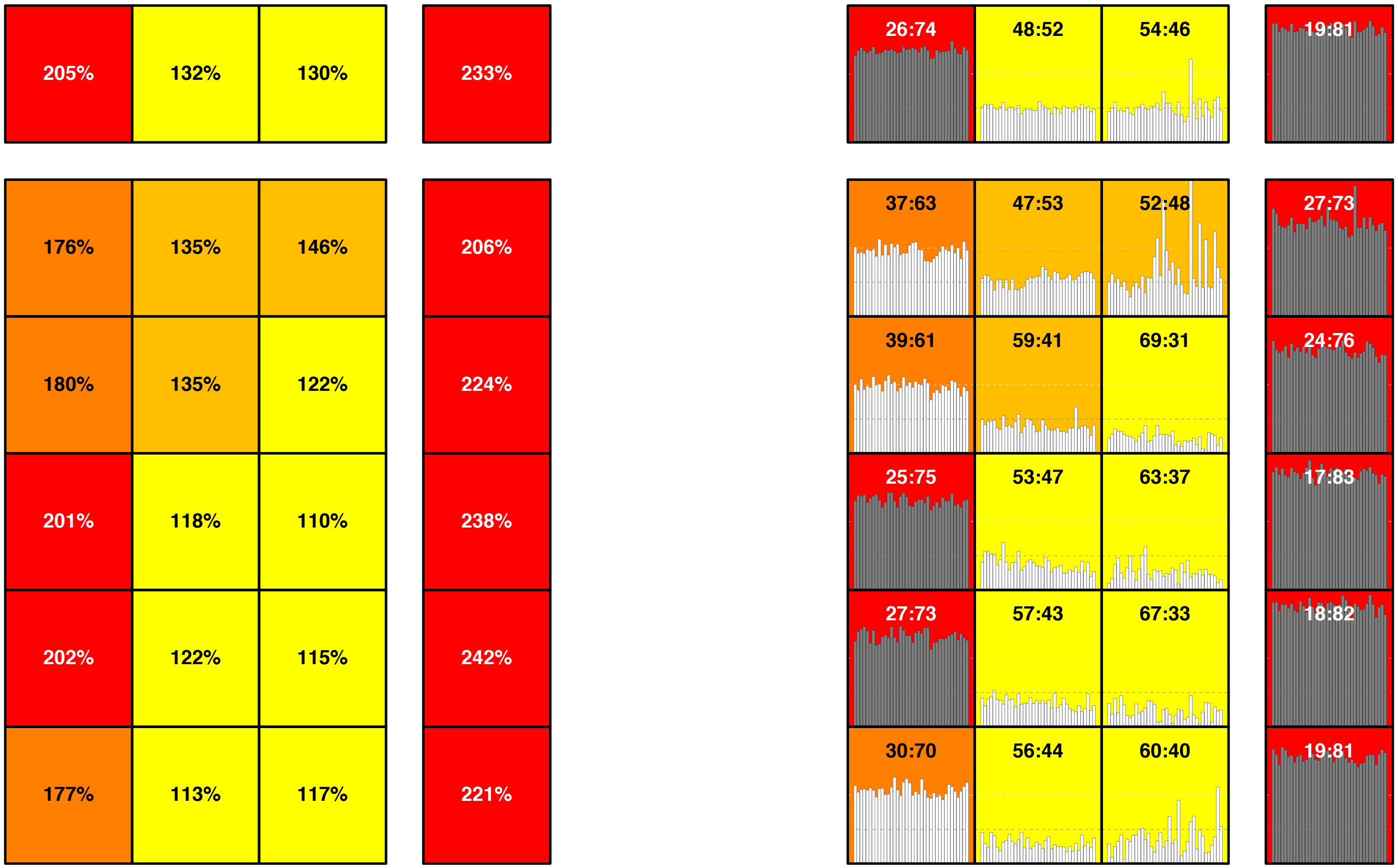
1. Regions
   Center Grid
2. Circumferential Bands
   Right Column
3. Axial Bands
   Top Row
4. Sheet & Run
   Top-Right Cell



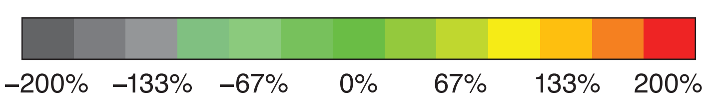
Sampled area of portrait presses divided into 5 x 3 regions showing imprecision trends.



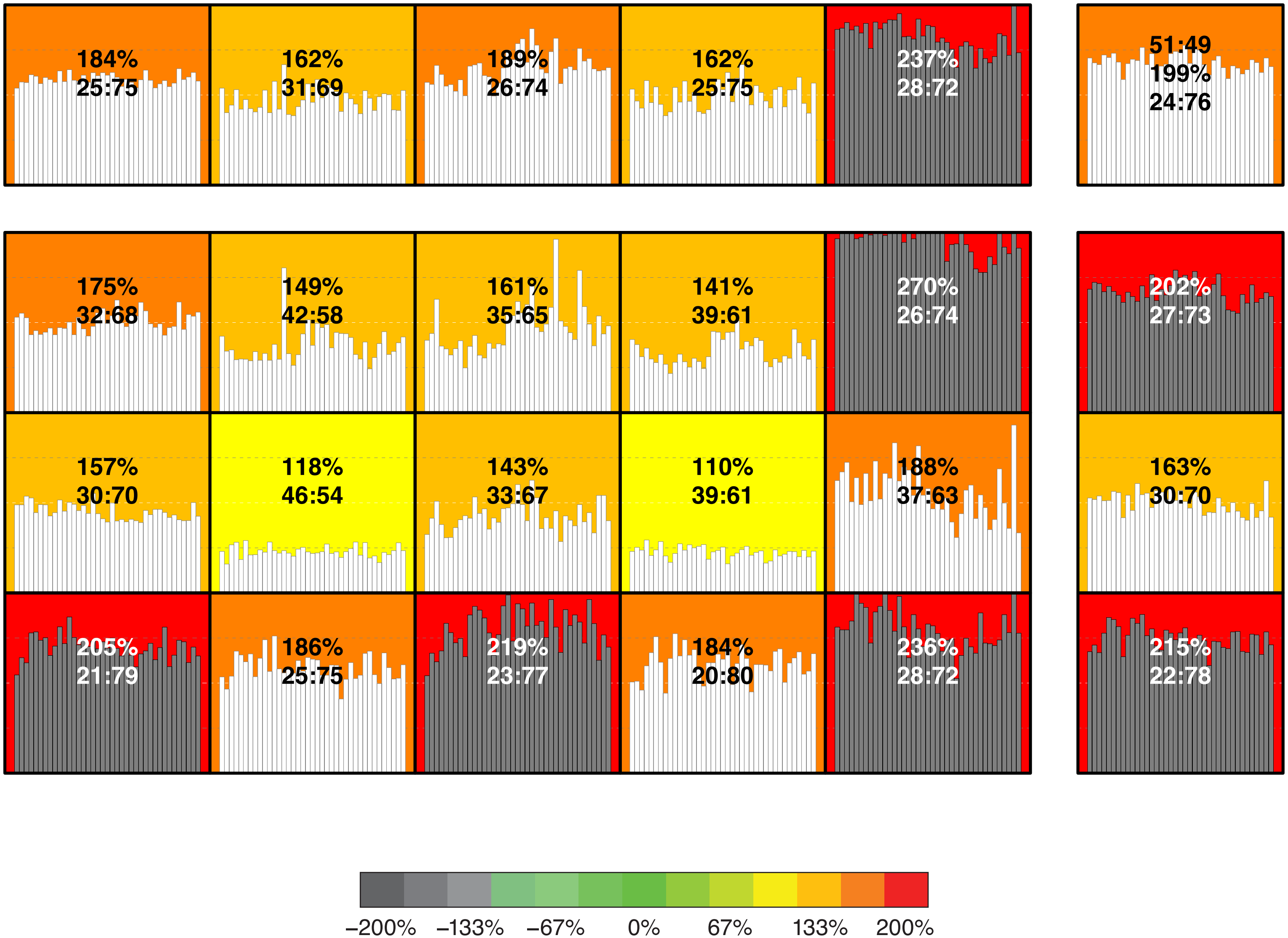
Spatial-Temporal Imprecision



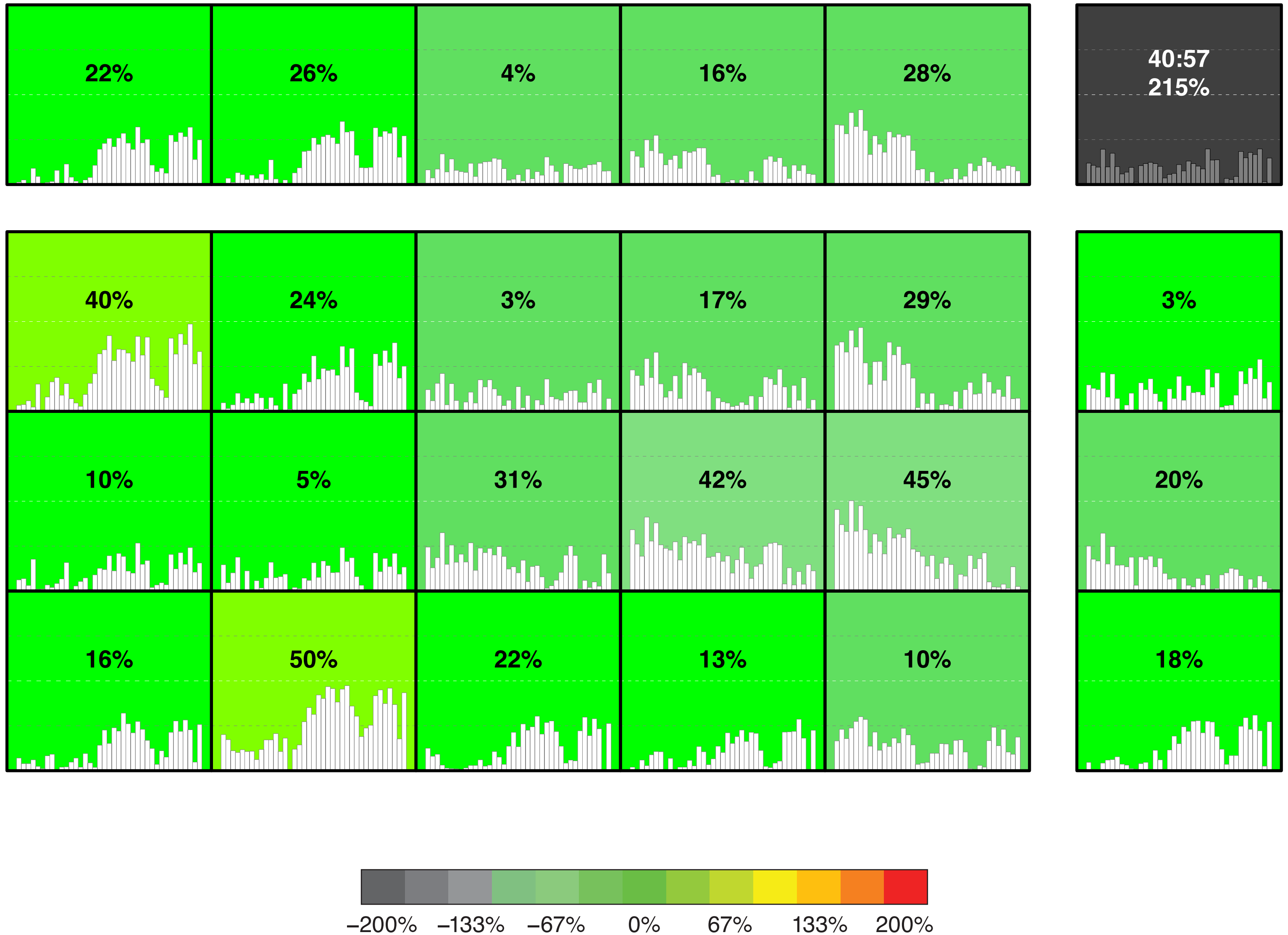
Portrait presses divided into 5 x 3 regions showing imprecision scores (left) & factors (right).



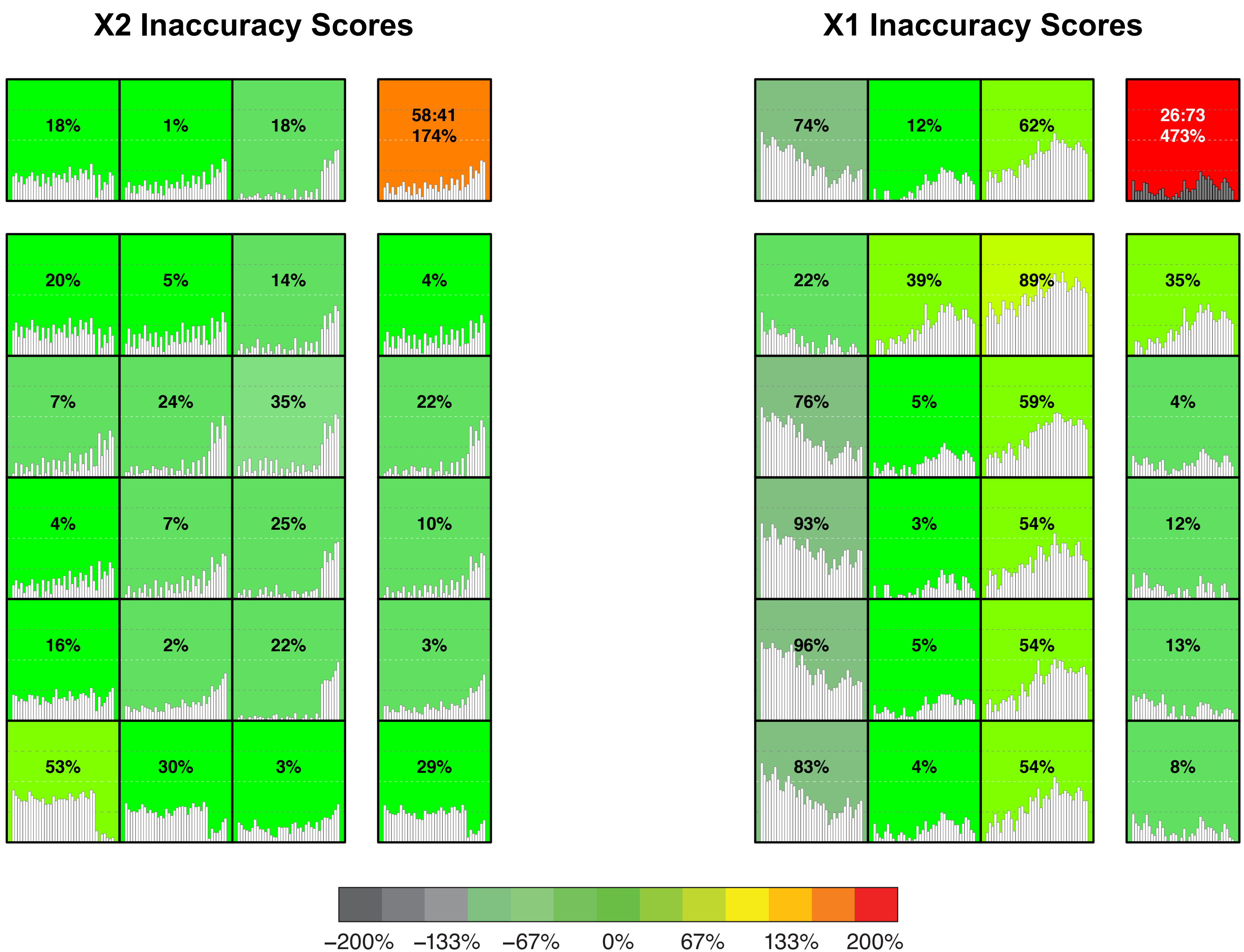
Spatial-Temporal Imprecision



Spatial-Temporal Inaccuracy



Spatial-Temporal Inaccuracy



Thank you!