Why Measure?
- Color communication
- Language problems
- Color subjectivity
- Your brain on color
- Color reproduction
- If you don’t control it, you can’t manage it
- Color Management
  - For fast approvals
  - Improved communications

Why use an instrument?
- Communication
- Consistency
- Problem isolation
- Detection of Change

What is Color?
- Is the grass green?

What is necessary to see color?
1. Illumination - a light source
2. Sample or object to interact with the light energy
**What is necessary to see color?**

1. Illumination - a light source
2. Sample or object to interact with the light energy
3. A receiver and processor (eye)

---

**Light is Color**

- ‘White’ light from different sources provides different relative energy levels.
- The light source under which a sample is viewed will affect the color we see.

---

**Objects have no color**

- Is an orange orange?
- What color is outer space?
- No object, no color
- No light, no color

---

**Color Theory**

- Color is explained by 2 theories:
  - Additive Color Theory
  - Subtractive Color Theory
Additive Color Theory
- Red + Green + Blue = White
- Example: Color TV or Monitor

Subtractive Color Theory
- Cyan + Magenta + Yellow = Black
- Example: Color Printing

So what about us?
- What part do our eyes play in the world of color?
- How can we test our visual system?
- Do we all see the same?
- How can we know?

What is the ‘best’ color tool?

Why use a Color Measurement Instrument?
Look at the ‘X’

Limitations

- Retinal Fatigue -
  - Brief exposure to strong colors leaves an afterimage.
  - Considerable rest is required to refresh the eye’s rhodopsins.
Limitations

- Retinal Fatigue -
- Poor Color Memory -
  - A colorist knows that two objects must be viewed simultaneously in order to fully judge their differences.

Different Grays?

No, Same Gray!

Same Oranges?
Same Oranges!

Limitations

- Retinal Fatigue -
- Poor Color Memory -
- Background Effects -

While the Fovea does indeed see greatest detail, it is not possible to turn off the input from the rest of the eye. A good colorist must be always aware of his total field of view!
Limitations

- Retinal Fatigue -
- Poor Color Memory -
- Background Effects -
- Colorblindness -
  - One male in 13 suffers from red / green colorblindness. Females do better statistically... one in 300 suffers the same genetic deficiency.
- Lighting conditions -
  - ‘Light is color’: failure to adopt good viewing habits often results in bad color decisions.

Limitations

- Retinal Fatigue -
- Poor Color Memory -
- Background Effects -
- Colorblindness -
- Lighting conditions -
  - ‘Light is color’: failure to adopt good viewing habits often results in bad color decisions.

Limitations

- Retinal Fatigue -
- Poor Color Memory -
- Background Effects -
- Colorblindness -
- Lighting conditions -
- Recordability -
  - Stress, time of day, fatigue, ambient conditions... all will affect the way in which we see color.

Limitations

- Retinal Fatigue -
- Poor Color Memory -
- Background Effects -
- Colorblindness -
- Lighting conditions -
- Recordability -
  - Age -
  - Yes friends... as we age our visual response changes.
Understanding Color Instrumentation

- Densitometers
- Colorimeters
- Spectrophotometers

Densitometry

- Transmission

- Reflection
Diagram of a Densitometer

- Uses apertures to locate the object
- Uses three filters to differentiate colors of light
- Uses receiver to determine the amount of light

REFLECTANCE!

Densitometer

- How it views the spectrum
  - Status defines the view
    - Status T the ANSI standard
    - Status E the DIN standard
    - Status A and M for Photo

Typical Densitometers

- Transmission or Reflection
- Strip reading
- Manual
- Spectrally based

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Application of Densitometry

- Process control
- Quality control
- Calibration

\[
\frac{\text{Actual Ink}}{\text{Standard Ink}} = \text{Result}
\]

Reflection Densitometer Functions

- Density
- Print Contrast
- Dot/Tonal Value
- Hue/Gray
- Trap

Print Characteristics

- Density
- Print Contrast
- Dot Area / Dot Gain
- Hue Error / Grayness
- Trap

Why Do We Measure Density?

- Measuring ink on the press sheet
  - Solid ink density (SID)
    - During make-ready to bring the press up to color
    - During press run to match an OK sheet
    - Monitor the consistency of a run

What is Density?

- Density is not linear
  - Density units are larger at low numbers
  - Density units are smaller at high numbers

Why Do We Measure Density?

- Calculate other Print Characteristics
  - Dot Area / Dot Gain
  - Trap
  - Print Contrast
  - Hue Error / Grayness
Where Do We Measure Density?

- Color Bars
  - Always the best choice
  - Use a bar that best helps you control your press/process

Where Do We Measure Density?

- Image Area
  - Avoid if possible
  - Read solid areas only (banners)

What Do the Numbers Mean?

- Reflect the amount of ink on paper
  - Ink film thickness increases, the density numbers rise
  - Ink film thickness decreases, the density numbers fall

What Density Values Should We Use?

- Set up a range to run within
  - Establish a target density and limits

TARGET - LIMIT

What Density Values Should We Use?

- Specifications for different types of printing:
  - SNAP
  - Specifications for Non-Heat Advertising Printers
  - GRACol
  - General Requirements for Applications in Commercial Offset Lithography
  - SWOP
  - Specifications Web Offset Publications

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What Density Values Should We Use?
- Typical Density Values

Print Characteristics
- Density
- Print Contrast
- Dot Area/Dot Gain
- Hue Error/Grayness
- Trap

What is Print Contrast
- Difference between a Solid and Shadow Tint
- Measure of shadow detail
- Print Contrast = \( \frac{D_s - D_t}{D_s} \times 100 \)

Why Do We Measure PC?
- Monitor ink and water balance
- Determine plugging in shadow region
- Determine optimal target SID value

How Do We Measure PC?
- Must measure in a color bar
- Measure
  - Solid Ink Density Patch
  - Shadow Tint Area of 75%-80%

What Do the Numbers Mean?
- Changes point to problems
  - Water Balance
  - Paper/material
  - Solid ink density
  - Dot Gain (TVI)
What Values Should We Use?

- Typical Print Contrast Values

Related Topics

- Using PC to determine optimal SID values
  - Start press run with low solid ink densities
  - Pull samples, measure SID and PC
  - Increment density
  - Graph results
  - Peak is optimum

Print Characteristics

- Density
- Print Contrast
- Dot Area/ Dot Gain (TVI)
- Hue Error / Grayness
- Trap

Why Do We Use Dots?

- Can not print continuous tones
  - Ink on; Ink off
  - No shades
  - Different size dots simulate continuous tone

What is Dot Area?

- Estimated ink coverage of a tint patch
- Based on the density...
  - of the paper (Dp) = 0%
  - of the solid (Ds) = 100%
  - of the tint area (Dt)

\[
\text{Dot Area} = \frac{1 - 10^{-n(Ds-Dp)}}{1 - 10^{-n(Dp)}} \times 100
\]

- An n factor of 1.00 yields the Murray-Davis equation for dot area.
- An n factor other than 1.00 yields the Yule-Nielsen equation for dot area.

What is Dot Gain (TVI)?

- Indication of increase of dot size
- Based on the dot area...
  - Press Sheet Dot Area minus Film Dot Area

\[
68\% - 50\% = 18\% \text{ Dot Gain (press sheet)} \quad (\text{film})
\]
Why Do We Measure Dot Area?
- Determine if press is printing tones consistently
- Controlling dot gain on press

How Do We Measure Dot Area?
- Must read Substrate & Solid Ink Density
- Color bars are easiest to use
- Difficult to find in image area
- Accuracy in measuring
- Read on a consistent surface
- Be aware of backing on sheet
- Use a solid near the tint

What Do the Numbers Mean?
- Dramatic changes point to problems
  - Plate wear
  - Oxidation
  - Ink/Water balance
  - Solid ink density
  - Ink Emulsification/change in Ink Tack
  - Doubling/Slurring
  - Picking

What numbers should we use?
- Typical Mid-Tone Dot Gain Values

Related Topics
- Optical Vs Mechanical Dot Gain (TVI) . . .
- Using an N-Factor . . .
- Reading Plates . . .

Mechanical Vs Optical Dot Gain (TVI)
- Mechanical——(9%)
  - Any physical growth of the dot
    - Doubling or Slurring
    - Fill In
    - Growth created by pressure of the press
- Optical---------(11%)
  - Dot gain due to light scattered / absorbed by substrate
  - Shadowing effect
N-Factor

- Changes the Dot Value
  - The higher the n-factor the lower the dot area will read.
  - This also known as “Fudging” the numbers.
- When to use it
  ✓ Fingerprinting
  ✓ Imagesetter calibration
  ✓ Plates

Reading Plates

- Reading Plates
  ✓ Accuracy
  ✓ Consistency
  ✓ Difficulties

Print Characteristics

- Density
- Print Contrast
- Dot Area/ Dot Gain
- Hue Error / Grayness
- Trap

What is Hue Error and Grayness?

- HUE ERROR measures larger component
- GRAYNESS measures smaller component

Why Do We Measure H/G?

- Quality Control of incoming inks
- Check for back-trapping

Inks are not pure; they appear to be contaminated
- Each ink has TWO “unwanted” components
  - Larger component changes HUE of the Ink
  - Smaller component makes the ink GRAY

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Why Do We Measure H/G?

- Quality Control of incoming inks
- Check for back-trapping
How Do We Measure H/G?

- On the Press Sheet
  - Measure Solid ink density patch
    - Color bar (preferred) or image area
  - Draw downs from ink Manufacturer
  - Find an area with densities similar to densities you run on press
  - Subtract Paper!!
  - Measure H/G in this area

What Do the Numbers Mean?

- Changes in Hue Error & Grayness indicate
  - Variation in ink formulation
  - Solid ink density shifts
    - Affects H/G of Traps

What Numbers Should We Use?

- Typical Hue Error Values

<table>
<thead>
<tr>
<th>Cyan</th>
<th>Magenta</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheetfed Offset</td>
<td>20%</td>
<td>46%</td>
</tr>
<tr>
<td>Web offset</td>
<td>21%</td>
<td>50%</td>
</tr>
<tr>
<td>Non-Heat set web, News</td>
<td>28%</td>
<td>58%</td>
</tr>
</tbody>
</table>

What Numbers Should We Use?

- Typical Grayness Values

<table>
<thead>
<tr>
<th>Cyan</th>
<th>Magenta</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheetfed Offset</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>Web offset</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>Non-Heat set web, News</td>
<td>42%</td>
<td>34%</td>
</tr>
</tbody>
</table>

Print Characteristics

- Density
- Print Contrast
- Dot Area/ Dot Gain
- Hue Error / Grayness
- Trap

What is Apparent Trap?

- The ability of an ink film to adhere to another ink film, compared to its ability to adhere to paper.
  - The calculation is a percent from 0% to 100%
  - Due to Additivity Failure, 100% Apparent Trap may not be attainable; it’s a relative measurement only.
  - Apparent Trap Calculations are only meaningful if the process color printing sequence is known!
Why Do We Measure Trap?

- Check for proper overprinting
- Monitor ink tack
- Check the opacity of the yellow ink

How Do We Measure Trap?

- Must know the ink sequence on press
- Must be measured from a color bar

What Do the Numbers Mean?

- Changes in Trap Values Indicate:
  - Variation in ink properties or sequence
  - Solid ink density shifts
  - Ink and water balance problems
  - Paper/substrate problems
- Do I always need 100% Trap???
  - Not necessarily!

What numbers should we use?

Typical Apparent Trap Values

- Sheetfed
  - Red: 70%
  - Green: 80%
  - Blue: 75%
- Offset
  - Red: 70%
  - Green: 80%
  - Blue: 75%
- Web offset
  - Red: 65%
  - Green: 75%
  - Blue: 70%
- Non-Heat set web, News
  - Red: 55%
  - Green: 65%
  - Blue: 60%

Colorimetry
Press Room Color Control

Colorimeter
- How it views the spectrum

Mimics the eye
- CIE measurements
  - XYZ
  - L*a*b*
  - LCH

Color: Hue, Value & Chroma
- Three independent variables
- A three-dimensional model like:
  - longitude, latitude, altitude
  - length, width, depth.

Albert Munsell was the first person to present a practical color order system by which an individual could specify color-by-the-numbers.

C.I.E. L*a*b* 1976

Power C: L* = 64.00, a* = 3.72, b* = 49.26
Typical Colorimeters

- Reflection or Emissive
- Auto Scanning
- Manual

Spectrophotometry

Typical Spectrophotometers

- Transmission or Reflection
- Auto Scanning
- Manual
- Tethered

Applications - Colorimeters and Spectrophotometers

- Quality Assurance
- Profile Creation
- Color Specification
- Formulation

Diagram of a Spectrophotometer

Uses 16 Filters to break up light
SpectroDensitometry

Densitometer + Colorimeter + Spectrophotometer
Spectrodensitometer

SpectroDensitometer vs Densitometer
- SpectroDensitometers
  - Color levels
  - Density
  - Print Attributes
  - Spectral data
  - Color Space
  - Color difference
- Densitometers
  - Color levels
  - Density
  - Print attributes

Diagram of a SpectroDensitometer
- Uses apertures to locate the object
- Uses several filters to differentiate colors of light
- Uses receiver to determine the amount of light

Benefits
- SpectroDensitometer Benefits For applications in printing
- The “Top Ten List”
1) Accuracy and Agreement
- Provides high accuracy:
  - Improvement over filter densitometers
- Inter-instrument agreement:
  - For comparison of data within extended color control systems
  - Allows data to be compared with confidence
  - Allows color validation “by the numbers”
  - +/- .01 Density agreement

2) Densitometer Status
- Spectrophotometers calculate density
- Easily select from among standard densitometer responses:
  - Status T
  - Status E
  - Status A
  - Status I
- New responses too – HiFi
- No physical instrument modifications

3) Versatility in Application
- Full-featured spectrodensitometer
- Calculate multiple functions:
  - Density functions
  - Colorimetry
  - Spectrophotometry
- User selects function based on use
- A single instrument serves all needs

4) Color Management
- Spectrocolorimetry is most accurate
- For creation of ICC profiles
- Useful for print analysis
- Future growth expected
- Investment today allows use of color management when user is ready

5) Color Specification
- Spectrophotometry is the most descriptive way to identify a color
- This language enables precise color communication via workflow
  - Client selects color standard
  - Designer specifies color spectrally
  - Ink-manufacturer formulates it
  - Printer monitors press run
  - Client verifies final printed color

6) Color Assurance
- Some color characteristics cannot be evaluated using simple densitometry
- Light gray or pastels
  - Show minute density difference (.03)
  - Color difference unacceptable (4DE)
- Pigment bronzing
  - Escapes detection by densitometer (.02)
  - Spectrophotometers respond (3.5DE)
7) Comparative Evaluation
- Compare color from varied samples:
  - Ink draw-downs
  - Previously printed materials
  - Provided color swatches
  - Production print run
- Density useful for process color – less meaningful for many special colors
- Colorimetry and spectrophotometry yield more meaningful comparisons

8) Match Visual Evaluations
- Densitometers provide:
  - Hue Error and Grayness
- May not always be relative to perceived color differences
- Colorimetry with color tolerancing:
  - Provide color evaluation that emulates visual color matching

9) Substrate Evaluation
- Colorimetric substrate QC is possible
  - Brightness
  - Whiteness
  - L* a* b*
- Densitometry does not perform well
- Spectro can calculate colorimetry
- Control all colorant & paper variables

10) Upgrade Capability
- Can start with only density functions
  - Upgrade to add dot & other functions
  - Upgrade to a spectrophotometer
  - Upgrade to a full spectrophotometer
  - Based on growth in needs
- Spectral engine underlies technology
  - Downloadable instrument firmware enables upgrade

Instrument Choices
- Type of data needed
  - Price
  - Speed
  - Ease of use
  - Application

The Goal
- Consistent color
- Accurate color
- Reduce waste/ downtime
- Make it easy
- Better communication
The Solutions
- Color measurement
- Color specification
- Print process control
- Color management

Color Measurement and Management: Results
- Color consistency
- Color accuracy
- Color communication
- Reduce waste
- Increase productivity
- Make it easier

Who’s out there?
- www.x-rite.com
  - Color Enabled Partners
    - Calibration
    - Color Management
    - Consultants

Pressroom Color Control Measurement and Management

Questions?
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