Total Measurement Uncertainty Analysis in Color Measurement

Jack A. Ladson[1], Hugh S. Fairman[2]

1. Color Science Consultancy

Yardley, PA 19067 USA

2. Hemmendinger Color Lab

Tatamy, PA 18085 USA

The uncertainty of a measurement is expressed by stating a range of values that encompasses the true value of a measured quantity. Uncertainty is typically expressed as the measured value plus or minus the uncertainty value. Uncertainty of a measurement system usually has identifiable components such as the instrument, the operator, and the colorimetric uncertainty of the specimen, which we call uniformity. One can see that a specimen that is not the same color everywhere on its surface presents a greater uncertainty of measurement than one that is the same color over its entire surface.

The three components of total measurement uncertainty are instrument uncertainty, operator uncertainty, and uniformity uncertainty. These three components of uncertainty, along with the bias of the measurement system, if any, comprise the total measurement uncertainty of a color measurement system.

This total measurement system uncertainty is useful to:

1. Determine accuracy of: instrument profiles, device dependent profiles, and gamut maps;
2. Determine product tolerances, process capability, and production tolerances; and
3. Determine the number of significant digits to report, evaluate performance of different instruments,
4. Determine whether multiple measurements ought to be made, and many other needed colorimetric tasks.

What is not apparent is that the uncertainty of measurement varies with each component of the measurement system, and the value of each component does not carry forward to another measurement system. While one might realize that the instrument uncertainty might vary from instrument to instrument, it is also true that the operator uncertainty and the uniformity of the specimen vary widely from instrument to instrument, and from specimen to specimen. Therefore, the only way in which the total measurement uncertainty of the measurement system may be derived is experimentally employing the specific conditions of measurement.

The following table shows results obtained from a typical analysis of a printed-paper specimen and a black plastic specimen. Uncertainty values were obtained for component tristimulus values X, Y, and Z, for CIE notations L*, a*, and b*, as well as ΔE*. The columns CIU, COU, and CUU stand for component instrument uncertainty, component operator uncertainty, and component uniformity uncertainty, respectively. The analysis was carried out on two instruments: one an ultra small specimen port (6 mm) with an 8 cm diameter sphere, and the other a large area view specimen port (25 mm) in a 12 cm sphere. The ultra small specimen aperture is representative of those instruments deployed in the graphic arts industry and the large specimen area in industries where spatial averaging of the surface is indicated.

Uncertainty results from two specimens on two instruments

Figure 1- Total Measurement Uncertainty Yellow Printed Card

UNCERTAINTY VALUES FOR TWO DIFFERENT SPECTROMETERS-Yellow Printed Card								
	Instrument		Operator		Specimen		Instrument 100	Instrument 500
	CIU-100	CIU-500	COU-100	COU-500	CUU-100	CUU-500	Total Uncertainty	Total Uncertainty
X	0.01	0.02	0.04	0.02	0.88	0.06	0.88	0.60
Y	0.03	0.02	0.03	0.02	0.79	0.57	0.79	0.57
Z	0.01	0.00	0.07	0.02	0.09	0.27	0.11	0.27
L*	0.02	0.01	0.00	0.02	0.46	0.33	0.46	0.33
a*	0.03	0.01	0.00	0.03	0.14	0.09	0.14	0.09
b*	0.05	0.02	0.30	0.07	1.02	0.87	1.06	0.87
DE*	0.06	0.02	0.29	0.07	1.13	0.92	1.17	**0.92**

Figure 2- Total Measurement Uncertainty Black Plastic

UNCERTAINTY VALUES FOR TWO DIFFERENT SPECTROMETERS -Black Plastic								
	Instrument		Operator		Specimen		Instrument 100	Instrument 500
	CIU-100	CIU-500	COU-100	COU-500	CUU-100	CUU-500	Total Uncertainty	Total Uncertainty
X	0.00	0.00	0.02	0.00	0.48	0.23	0.48	0.23
Y	0.00	0.00	0.02	0.00	0.52	0.25	0.52	0.25
Z	0.01	0.00	0.02	0.00	0.69	0.34	0.69	0.34
L*	0.01	0.01	0.05	0.00	1.52	0.74	1.52	0.74
a*	0.03	0.01	0.03	0.00	0.15	0.09	0.15	0.09
b*	0.05	0.02	0.03	0.00	0.75	0.43	0.75	0.43
DE*	0.05	0.02	0.05	0.00	1.69	0.84	1.69	**0.84**

Author Biography

Jack Ladson currently is a principle in Color Science Consultancy, which supplies color solutions throughout the enterprise, solving industrial problems. For twenty-five years Ladson has worked in the field of color and appearance technology, pioneering new technologies. His interests are in digital color technology, color appearance phenomenon, spectrophotometry & colorimetry, gonioapparent pigments, and global color control. He has extensive experience in many aspects of business.

Ladson is a past –president and currently serves as Secretary of the ISCC. He is an active member of the American Society for Testing and Materials (ASTM). He chairs the sub-committee ASTM E12.02 on Colorimetry and Spectrophotometry, E12.06 on Digital Imaging, and is task group chairman of Effect Coatings (Metallic and Pearlescent). He is a member of the BOD of the Society Plastics Engineers, SPE. He is a member of International Imaging Association, I3A. He served as an advisor to PENN State Advisory Board on Nanoparticles. Ladson is an invited lecturer in the US, Europe, and Asia; and has published over 30 papers on color and color appearance.