

THE SECOND C: Modeling Fabric Hand for the Apparel Industry

By Keith Hoover

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We who work in color management owe a debt of gratitude to the countless people in academia and industry who defined and built the model of color that forms the basis for modern commercial color management. It allows us to effortlessly define, categorize, compare, and formulate color.

Given the ubiquity of digitalization in 2025, one might fail to understand just how far our industry has come in the past 40 years. Prior to that, dealing with color was an “art” exercised by those with extensive experience in dyeing (and not all experience is good experience). New technology using color instruments, software, and various metrics and equations has improved the consistency, manufacturing speed, and quality of finished textiles.

But color is only one attribute of a fabric. After color, hand [1] is the most important subjective property of fabric. However, those involved in fabric development for apparel brands are hard-pressed to manage it consistently

since there is no industry-accepted, commercially viable process to objectively characterize hand. Thus, an apparel brand can neither tell a fact-based story to promote fabric hand as a product attribute nor effectively manage its supply chain.



*Like color, hand is a psycho-physical phenomenon.
Illustration generated by newarc.ai*



Once attracted by color, the customer feels the fabric. Hanger design by M. C. Escher. Illustration generated by newarc.ai

PROJECT ROADMAP

The purpose of this article is to announce Project Roadmap, an initiative to objectively model hand as a fabric attribute. [2] This involves characterizing, measuring, categorizing, and comparing the hand of various fabric samples as the basis for creating a digital model to define tactile appearance. A key requirement of any model is to assess how it correlates to the subject it is mimicking. The successful development of this capability will provide a roadmap for new technology that benefits the textile industry by simplifying fabric development and assessment.

Ideally, this project should involve organizations that promote the wellbeing of the fashion, textile, and apparel industries (like the AATCC), yarn, fabric, and apparel manufacturers (the supply chain) who will benefit from more objective specifications, and apparel brands, who will better be able to communicate what they want.

Academia may well play a role—as long as their objective is to help commercialize a solution and not study the thing to death. Ultimately, the hand test instrument providers will be involved by providing instruments for evaluation. However, their commercial influence in the project must be tempered by the requirement to supplant old-fashioned, subjective hand assessments with a new digital industry standard benefitting all.

Some apparel brands might be inclined to develop this project in secret, thus making their hand solution proprietary. However, that would be bad for the industry since it would pit “my practices” against “best practices.” What we really need is cooperation between brand competitors. Competing brands share the same supply chain—it’s the quality and design of a product, not where it is made, that differentiates it from its competitors (well, that and marketing). So too, the way that hand is digitized won’t make one apparel company better than the other—the fabrics it selects (not the means of digitization) will deliver the right sensation to the customers.

Please contact Black Swan Textiles to support and participate in Project Roadmap. [3]

The following outlines how Project Roadmap will proceed.

STAGE 1—CAN HAND BE EXPRESSED DIGITALLY?

The purpose of the work done in Stage 1 is to establish a baseline for how hand is currently managed and then to determine if hand can be digitally modeled, categorized, and evaluated.

Phase 1—the Analog Baseline

In Phase 1, we will first procure a set of test fabric samples to be used for all methods of hand assessment described in the following phases. These samples must have a variety of surface textures likely to be different in hand to adequately represent the breadth of samples encountered in commercial product development.

Next, we will establish a baseline to define the status quo of manual hand assessment. We will identify and recruit a group of industry subject matter experts (SMEs) in the field of fabric development to assess the test fabric samples procured in Phase 1. We will devise a process in which each SME reviews, characterizes, and records an assessment of each sample in the set multiple times over the course of a set period of time. With this data, we will determine the repeatability and reliability of the manual method of hand assessment by comparing the results of each SME to that of the others and also to each SME’s other assessments. In



Fabric SMEs Mary, Darryl, and Darryl methodically evaluate hand. Illustration generated by newarc.ai

short, we will determine if the SME’s agree with each other and if they agree with themselves.

Phase 2—the Digital Landscape

Phase 2 will identify and document commercial test instruments that measure hand, noting the strengths and weaknesses of each. All candidates must meet Manufacturing Readiness Levels (MRL) 8 or above. [4] If commercially viable, then pricing and availability will be noted.

Phase 3—Digitization

Digitization is the conversion of a physical object into a set of numbers (data). Scanners convert printed documents into image files (like jpgs). Spectrophotometers convert colors into spectral data (like qtxs).

In Phase 3, we will digitally measure the test fabric samples using the hand testing instruments identified in Phase 2. The first task will be to obtain access to the hand testing instruments from the owners. The next task will



No, digital hand test instruments don’t look like this, but isn’t it a cool illustration? Illustration generated by newarc.ai

be to execute the testing. We will follow the same procedure used in Phase 1 for manual hand assessment and measure the test fabric samples multiple times over the course of a set period of time.

Phase 4—Assessing Digitization

Phase 4 will analyze the results from each hand testing instrument identified in Stage 2 by evaluating the repeatability and reliability of the data produced by the digital testing methods. Again, we will compare all the data to determine if the results of the various instrumental methods agree with each other and if they agree with themselves.

Assessing Stage 1 Results

When Stage 1 is complete, we will summarize the repeatability and reliability of the current manual hand assessment method. Then, we will review the results of the various hand testing instruments and determine if it is likely that fabric hand can be reliably digitized and digitalized.

The criteria for a positive determination are twofold:

1. The status quo of the manual hand assessment method must be seen as unreliable and worthy of improvement.
2. The results of the hand testing instruments must be repeatable and indicate that some categorization of results into “hand groups” is possible.

A positive determination does not require that one of the existing hand testing instruments can be an out-of-the-box replacement for the status quo. There must merely be an indication that 1) hand can be digitized and 2) improvement can be made in characterizing the results into a reasonable model.

STAGE 2—DEVELOPING THE MODEL

The purpose of the work done in Stage 2 is to lay the groundwork for comparison and then evaluate the strengths and weaknesses of the various hand testing instruments identified in Stage 1.

Phase 1—the Language of Hand

In the field of color, by analogy, there are universal terms to describe color appearance. These include category descriptors such as hue, chromaticity, and lightness as well as general terms such as red, green, yellow, and blue to identify variations of color. No comparably precise language exists to identify hand, or the **tactile appearance** of fabrics.

AATCC RA89 *Hand Evaluation Test Methods* is a research committee established “to develop specialized test methods and terminology for the assessment and description of



*Designers need a better vocabulary to describe what they feel.
Illustration generated by newarc.ai*

differences in the hand of fabrics.” Its most notable output is “Evaluation Procedure 5-2024: Evaluation Procedure for Fabric Hand” [5], which suggests a methodology for evaluating hand that incorporates the following language:

Compression: hard, thin, thick, springy, fullness, bulky, firm, soft, lively, lofty, resilient

Bending: stiff, pliable, supple, crisp, limp, papery, lively, springy, boardy

Shearing: supple, clinging, tight, loose, firm, pliable, elastic, stretchy

Surface: coarse, rough, slippery, harsh, smooth, fuzzy, soft, scratchy, slick, waxy, nappy, oily, raspy, warm, cool

Hand, like color, is a psycho-physical phenomenon that relies on metaphors to provide a type of abstract comparison rather than precise definitions for understanding. For instance, a “springy” fabric is not literally a spring, but can be imagined to behave like a spring when compressed. Some of these terms make sense and others are kind of like using “romantic” or “bubble-gummy” to describe color. At any rate, they are ambiguous, at best (especially if entered into *Google Translate* at an overseas mill).

There are other shortcomings, too. As the procedure notes, even after its most recent revision, “some terms can be attributed to more than one physical property category,” namely

- “Springy” describes both Compression and Bending
- “Firm” describes both Compression and Shearing
- “Soft” describes both Compression and Surface
- “Lively” describes both Compression and Bending
- “Pliable” describes both Bending and Shearing
- “Supple” describes both Bending and Shearing

For colorists, imagine that “bright” described both Chromaticity and Hue.

These attributes and constituent elements described in the procedure are arbitrary and subjective as indicated in its Bias Statement: “Within the guideline techniques, bias, if any, cannot be determined, since there are no known procedures for determining the true values for the constituent elements of hand.”

So, in Phase 1, we will first research various approaches to describe different variations of hand and then compile an initial list of terms to describe tactile appearance. Then, we will work with our SMEs to identify specific fabric test samples that correlate to each of the tactile appearance variations. Based on that work, we will revisit the initial list and finalize a working hand vocabulary set.

Phase 2—Digitalization, Part 1

Digitalization is the process of monetizing data acquired through digitization by modeling a process that accom-

plishes a task in a novel way. The evaluation of the results for the various hand testing instruments in Stage 1 established that some categorization of results was possible.

This phase will identify capabilities and functionality that a viable hand testing instrument (hardware and software) must have to supplant manual hand assessment. Initial requirements include:

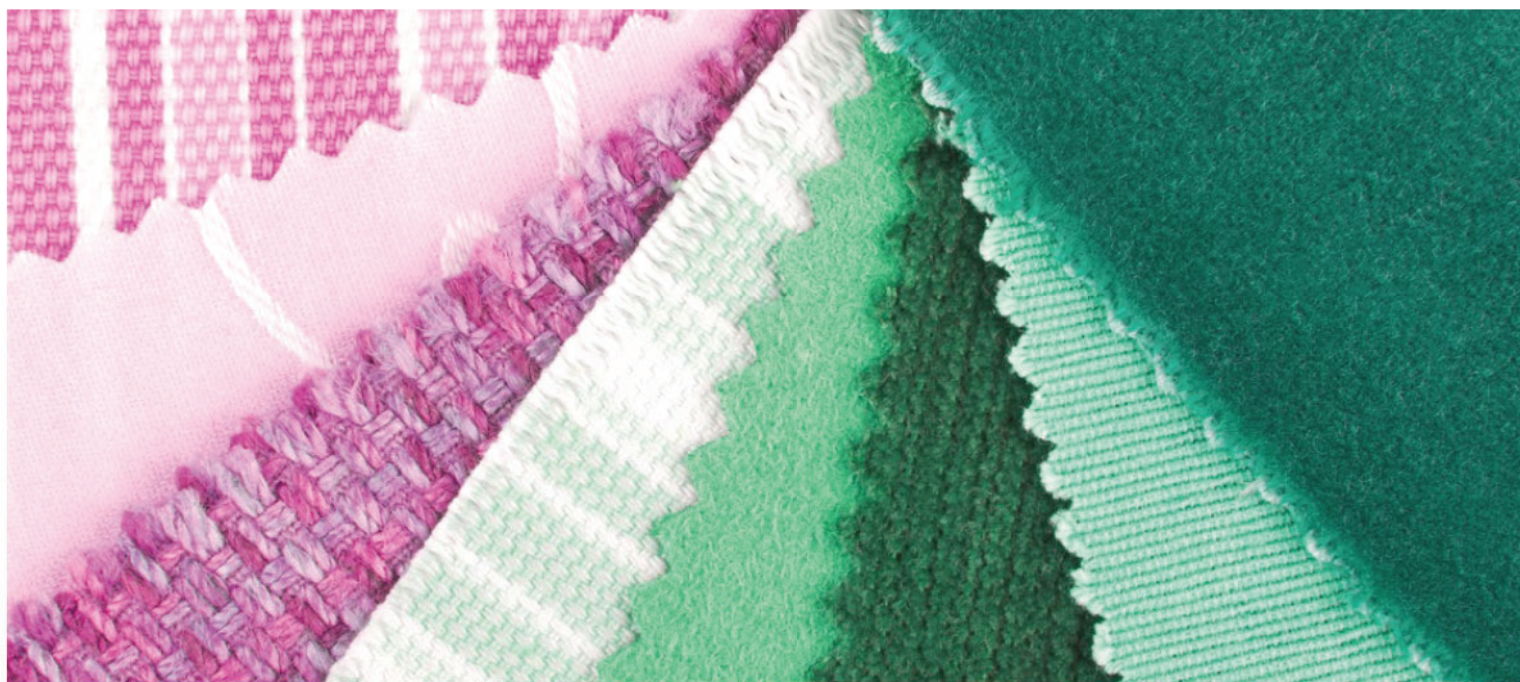
- 1) the ability to assign a numerical tactile appearance value to a fabric sample,
- 2) the ability to place a fabric sample in a given hand vocabulary category, and
- 3) the ability to compare the tactile appearance of a sample fabric with a standard fabric.

Phase 3—Digitalization, Part 2

The first task in this phase will evaluate how well the results of each hand testing instrument conforms to the hand vocabulary proposed in Phase 1. The next task will be to assess the capabilities of each hand testing instrument against the requirements set up in Phase 2.

Phase 4—the Wining Fan

In this phase, we will separate the wheat from the chaff and eliminate the hand testing instruments that fail to perform or meet the minimum requirements. If any candidates remain, then we will identify weaknesses and develop a “get well soon” plan to address these shortcomings with the technology owner.



Assessing Stage 2 Results

When Stage 2 is complete, we will evaluate the merits of all hand testing instruments to determine if at least one is a viable candidate for going forward. The criteria for a positive determination are twofold:

- First, a qualifying hand testing instrument must roughly mimic the manual hand assessment methodology by placing test fabrics into the proper hand vocabulary categories. Using color again as an analogy, if we identify the primary colors as red, blue, and yellow, then a digital solution candidate must not identify the primary colors as orange, green, and purple.
- Second, a qualifying hand testing instrument must generate data to produce the capabilities and functionalities identified in Phase 2.

A positive determination does not require that one of the existing digital hand assessment solutions meets all requirements. There must merely be an indication that 1) the technology can be revised to meet our requirements or 2) lacking required capabilities and functionalities, the data generated during the measurement process can be used to create them.

STAGE 3—COMPLETING THE MODEL

The purpose of the work done in this stage involves improving the performance of the successful hand testing instrument candidate(s).

Phase 1—Add More Samples

Phase 1 involves procuring more fabric samples from partner mills and measuring them on the hand testing instruments. We will identify and communicate with key mill partners to procure additional samples to add to the test fabric sample collection.

Phase 2—Baseline, Part 2

Phase 2 involves presenting the additional samples to the SME panel for manual hand assessment. We will repeat the review process devised in Stage 1, Phase 1 with both the SME panel and the hand testing instruments. With additional data, we will again characterize the repeatability and reliability of the manual method of hand assessment by comparing the results of each SME to that of the others and also to each SME's other assessments. In short, we will determine if the SMEs agree with each other and if they agree with themselves.

Phase 3—Assess

Phase 3 involves evaluating and correlating the results of each assessment method. Any trends or anomalies in the hand testing instrument results from this extended baseline test versus the original will be noted.

Phase 4—Correct

Phase 4 involves adjusting the digital key performance indicator (KPI) calculations to improve performance based on the observations in Phase 3. Extended test fabric samples will be re-measured and re-assessed to evaluate changes made to the digital model.



A lot of fabric test samples will be required for this project.

Assessing Stage 3 Results

When Stage 3 is complete, we will evaluate the performance of the hand testing instruments versus the SME panel as well as the accuracy of the overall digital assessment methodology. The criteria for a positive determination require improved ready-for-prime-time performance of the hand testing instruments results.

STAGE 4—THE DIGITAL SHOOT-OUT

This stage involves pitting the hand testing instruments against a panel of seasoned SMEs along with a panel of naive evaluators in a tactile appearance assessment show-down.

Phase 1—Ready

In this phase, we will assemble two human panels for manual hand assessment. The first will be the SME panel, making any changes or additions deemed necessary either by attrition or improved experiment design. The second panel will be a group of naive evaluators. The reasoning for the dual panel approach acknowledges that less experienced personnel, not seasoned SMEs, are involved in day-to-day fabric assessments done by apparel brands. Additionally, we will procure a forum to conduct the shoot-out. Video documentation will be considered (who doesn't love a good Western?).

Phase 2—Aim

In this phase, we will identify and assemble 50 fabric test samples for the shoot-out. We will poll the panelists for any special assessment-related items they might want (such as a pic glass, lighting, pixie dust, etc.) and make those items available for the participants. Additionally, we will supplement the assessment methodology established in Stage 1, Phase 1 with additional tasks including:

- **Hand characterization** of each sample (one by one): Describe what you feel
- Grouping fabrics into **similar tactile appearance categories**: Group fabrics together that feel the same
- **Describing the tactile appearance difference** between a submitted fabric sample and a hand standard: Describe how a sample differs from the standard
- **Assessing the acceptability** of a submitted fabric sample against a hand standard: Pass or fail a production fabric sample to the production fabric standard

Each exercise will be completed by the hand testing instruments and each panel member and repeated a set number of times over a given period of time.



*Wrong digit—Never bring a finger to a digital shoot-out.
Illustration generated by newarc.ai*



*Some neophyte fabric developers come up with "novel" ways to assess hand
(and deal with a runny nose). Illustration generated by newarc.ai*

Phase 3—Fire

It's show time. The two shoot-out panels and the hand testing instruments will review and assess the fabric test samples as set forth in Phase 2 (and may God have mercy on their souls).

Phase 4—Last Man Standing

In this phase, we will analyze experienced versus naive human performance along with the man versus machine results for repeatability and reliability on each exercise. We will also direct both panels to review and comment on the hand testing instrument results.



Assessing Stage 4 Results

When Stage 4 is complete, we will be able to document both the accuracy and precision of the experienced and non-experienced panel participants as well as the hand test instruments. We will also review the feedback from the panelists on the hand test instrument evaluations.

A positive determination could follow multiple paths. First, the hand testing instrument results could win the shoot-out by more reliably characterizing, categorizing, and comparing the hand of various fabric samples compared with the results of both panels. Or, the hand testing instruments results could win the shoot-out by more reliably characterizing, categorizing, and comparing the hand of various fabric samples compared with the results of the neophyte panel. Alternatively, the hand testing instrument results might indicate that further adjustments are necessary, and the project could return to Stage 3 for improvement. One desirable result would be the endorsement of hand testing instrument results by the SMEs and neophytes.

STAGE 5—EVANGELIZATION

This stage involves organizing and executing a roadshow to present the results to various players in the textile and apparel industry (apparel brands/retailers, mills, yarn

spinners, academia, industry trade groups, test methods organizations, and the industry press). The purpose is to foster support for adopting the methodology.

Assessing Stage 5 Results

This stage involves spreading the word regarding hand testing instruments and gauging potential industry acceptance. Success criteria involve not just positive feedback, but a willingness to adopt the method, at least for a proof-of-concept project.

ROAD, CART, HORSE

When it comes to technology, hardware sales (the cart) are driven by software (the horse). But software requires the right programs built on a correct model (the road). For example, digital color for textiles was developed in what amounts to an open-source model. With that in place, hardware and software were developed and competed in the market based on how they used the model to bring value to their customers.

Spectrophotometers and color matching software were high ticket items for mills 30 years ago. However, they became standard fare in every dyehouse because they

worked—delivering more first quality fabric faster than old-fashioned visual-based methods done by “experienced” master dyers.

When it comes to using technology to solve the hand problem, let's learn from color. Not only should we not “put the cart before the horse,” we should remember to build the road that leads to the right destination. And that “road” is a viable foundational model that correlates with human behavior. Doing this includes A/B testing and other analytical methods to establish correlation between the analog and digital models. Just as experiments were conducted using trained colorists to determine if new color difference equations more accurately predicted visual assessment decisions, any hand assessment technology must be tied to human hand assessment behavior.

And we have miles to go. So, let's ride.



Notes

1. Hand, also known as handfeel, handle, and haptics, refers to the tactile properties of a fabric. For purposes of analysis in this paper, “hand” will refer to the sensation experienced by a person and “tactile appearance” will refer to a mathematical model of hand (much like “light source” refers to an actual lamp while “illuminant” refers to the mathematical model of that lamp).
2. I wanted to call it Project Touchy Feely, but that didn't fit the metaphors used in the article.
3. Contact Keith Hoover via email, keith.hoover@blackswantextiles.com
4. Manufacturing Readiness Levels (MRL) is a 10-step matrix used by the Department of Defense to assess the maturity of a potential product. MRL 8 indicates that the product can be made in a pilot assembly line supporting a low output rate. For more details, refer to www.dodmrl.com/MRL_Deskbook_2022_20221001_Final.pdf
5. EP005-EP5-EP 5: Guidelines for the Subjective Evaluation of Fabric Hand, developed in 1990 by AATCC Committee RA89 (editorially revised and reaffirmed 2011); reaffirmed 2020; revised 2024, *Manual of International Test Methods and Procedures*, 2025.

Keith Hoover, President of Black Swan Textiles, implements manufacturing-centric digital processes for color and fabric development. He has implemented digital color management programs for Ralph Lauren, Target, Lands' End, JCPenney, and Under Armour, ultimately leading to a process that eliminated lab dips altogether. At Under Armour, Hoover championed the UA Lighthouse, driving digitalization and advanced manufacturing processes to explore local-for-local sourcing. He has worked hands-on in mills worldwide and is a frequent AATCC presenter.

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- Hoover, K. The Second C: Going To the LOO, Part 3: Chromalucense & the Golden Eye. *AATCC Review*, 2025, 25 (1), 24-30.
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