

The co-evolution of color and digital tools: a new logic for fashion design

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ABSTRACT

This contribution offers a critical analysis of color as a visual code within the digital workflow of fashion design, through a comparative investigation of two iconic brands: Prada and Armani. The study focuses specifically on product color design in digital environments—namely, its representation and material rendering—rather than on dyeing or industrial production processes.

The research unfolds across three levels—image, language, and material—and is based on a critical reading of visual and documentary data drawn from official fashion archives (1988–2024).

Through a five-phase periodization, the study highlights paradigm shifts in color design, illustrating how digital tools (such as Pantone systems, generative AI, and 3D simulation) have progressively transformed chromatic composition, affecting both visual coherence and the cultural semantics of color palettes.

Comparative analyses show that maximum chromatic fidelity is achieved through a conscious selection of material substrates (e.g., cotton vs. silk) and a formal design approach aligned with brand identity.

Findings reveal a measurable gap between algorithmic simulation and multisensory experience, which calls for perceptual calibration phases and the integration of semantic and affective parameters into the digital design workflow.

KEYWORDS Italian fashion, Pantone, digital tools, color design, chromatic language.

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1. Introduction

Since the second half of the twentieth century, fashion's color language has undergone a radical shift—from symbolic-artisanal frameworks to industrial logic and, more recently, computational paradigms (Barthes 2013). In the digital realm, color is increasingly treated as a computational output generated by algorithmic pipelines (Lab/RGB mappings, rendering, text-to-image systems), whose appearance depends on material substrates, devices, and immersive contexts (Manovich, 2013). This article critically examines the evolution of fashion's color language from the twentieth to the twenty-first century, with particular emphasis on the transition from analog approaches to digital workflows. Our aim is to clarify color's role as a visual code in digital product design, defining its affective-semantic dimension and the discontinuities introduced by digital tools.

2. The evolution of chromatic design: from traditional techniques to digital tools

Historically, color has served as a visual and cultural code: Renaissance ultramarine in Marian iconography signalled purity and wealth; Rococo pastels conveyed aristocratic lightness; with Picasso, color became psychological narration (Blue and Rose Periods). Long before the digital era, then, color already functioned as a semiotic, affective, and social language (Abelló, edited by, 2025).

In the twentieth century, fashion accelerated a chromatic shift—from symbolic, craft-based gestures to industrial standardization—culminating today in a computational logic that shapes new paradigms of digital fashion design. The move from “making” to “simulating” marks an epistemic turn: color is no longer merely a tangible material but a “parametric configuration” within digital environments (Flusser, 2011).

Pre-digital practices—hand dyeing, fabric painting, manual sampling—encoded cultural hierarchies and identities yet faced structural limits: low chromatic reproducibility, dependence on physical substrates (silk, cotton, wool), and high perceptual subjectivity (Kawamura, 2005).

Digital platforms have recast the designer–color relationship, shifting from descriptive systems to generative ones. Since the 1990s, Adobe Photoshop has evolved from numeric CMYK input to visual RGB/HSV/LAB interfaces. From 2023, several tools have scaled in digital-fashion workflows: CLO 3D enables volumetric prototyping with physically based drape simulation and PBR rendering of color/material/light—effective for visual prototyping rather than chromatic design per se; Marvelous Designer is analogous, focused

on garment morphology and fabric dynamics with basic color controls. Adobe Substance 3D (Designer / Sampler / Painter) centres on authoring PBR materials and procedurally generating realistic textures (UDIM, physical maps) to support rendering. For real-time/AR presentation, Unreal Engine and Unity are widely adopted (Adobe Inc., 2024).

2.1. Benefits and challenges of the digital transition

Digital tools deliver clear advantages—high colorimetric repeatability, real-time testing across diverse material substrates, and rapid, scalable customization. Yet they also introduce new challenges: diminished sensory engagement with physical materiality, algorithmic mediation of perception, and a risk of global aesthetic homogenization. Technological evolution is never neutral; it embeds cultural assumptions and semantic models that redefine the meaning of color in fashion design. Today, color functions as a visual–material language that structures identity and narrative, targeting cross-media perceptual coherence between physical and digital touchpoints (screens, print, AR/VR). Figure 1 maps the main stages of this transition: from 2D numerical tools (e.g., 1990s Photoshop), through hybrid platforms such as Marvelous Designer and Adobe Substance, to immersive, high-fidelity systems like CLO 3D (2023) (CLO Virtual Fashion, 2023). Along this trajectory, color becomes an integrated visual–material code within project communication and brand storytelling.

3. Toward an emotional and symbolic dimension of color

Despite the widespread adoption of digital tools for defining and managing color, its emotional and symbolic dimensions remain underexplored (Heller, 2025). Most software relies on standardized systems—Pantone, HEX, Lab—that rarely account for culturally and ritually embedded meanings in specific contexts. For example, red (Pantone 485 C) commonly signals passion or danger in Western settings (Pantone LLC, 2024), whereas in China it evokes celebration, good fortune, and marriage; conversely, white and gray—icons of purity or elegance in Europe—are ritual mourning colors in China (Pastoreau, 2005). Figure 2 illustrates these semantic divergences, showing that even digitally standardized color is subject to deep perceptual and cultural variation (Gage, 1993; Batchelor, 2000).

In global digital design, algorithmic neutralization risks erasing symbolic strata and collective memory, leading to aesthetic homogenization (Calefato, 2004). In interactive systems, neglecting cultural connotations undermines the emotional and narrative resonance of visual experiences.

Period / Software	UI Screenshot Preview	Color Selection Mode	Material Linking & Preview	Evolution of Color Logic	Keywords
Photoshop 1990s		Manual input CMYK / RGB numeric values	No material linking; static visual output	Color as technical input, isolated from visual/material context	Static color model, CMYK numeric logic
Photoshop 2020s		Interactive graphical selector; HSV / LAB space and hexadecimal code supported	Layer-based support; basic texture rendering	Color integrated into visual design but disconnected from material simulation	UI-based color selection; user-centered experience
CLO3D 2023		Pantone libraries and real-fabric simulation enabled	Color applied to 3D fabrics with realistic variation (reflectance, gloss)	Color = Material = Visual language + brand identity communication	Fabric simulation; Pantone integration; visual-material synergy
Marvelous Designer 2023		Limited palette selection; RGB / HEX supported	Morphology-focused workflow; minimal material interaction	Color as a visual contour element; secondary to volume modeling	3D garment modeling; draping; textile structure
Adobe Substance 2023		Advanced procedural color + texture generation	Physically accurate simulation (diffuse, gloss, bump)	Color as reactive digital matter; visual fidelity + material responsiveness	Photorealistic rendering; physically based textures

Fig. 1. Evolution of digital tools for color selection in fashion (1990–2023). All UI previews are simulated illustrations generated for academic use.

Color Sample	Pantone Code	HEX	RGB	Lab Values	Cultural Meaning (China)	Cultural Meaning (West)	Iconography
	485 C	#DA291C	218, 41, 28	46.41, 68.0, 50.99	Fortune, celebration, marriage	Passion, love, danger	
	Cool Gray 1 C	#F0F0F0	240, 240, 240	94.39, 0.2, 0.9	Mourning, spirituality, purity	Purity, wedding, peace	
	1235 C	#FFD100	255, 209, 0	83.39, 6.57, 81.7	Imperial power, authority, divinity	Happiness, alertness, energy	
	2965 C	#003865	0, 56, 101	14.91, 7.19, -28.93	Stability, wisdom, mystery	Authority, discipline, institution	
	Black C	#231F20	35, 31, 32	16.0, 1.0, 1.0	Solemnity, formality, darkness	Elegance, death, power	
	3288 C	#007A5E	0, 122, 94	45.28, -49.45, 9.46	Longevity, nobility, harmony	Nature, freshness, health	
	2685 C	#582C83	88, 44, 131	25.5, 40.2, -51.2	Royalty, divinity, mysticism	Nobility, luxury, spirituality	

Fig. 2. Cross-cultural interpretation of color symbolism in China and the West. The images in the iconography column are generated by Fan T. using AI-based tools to ensure copyright-free visualizations.

A significant gap thus persists between digital high-fashion design pipelines and material perception, raising a key question: can software be calibrated to encode semantic and affective dimensions?

Addressing this challenge requires an interdisciplinary approach integrating visual semiotics, perceptual psychology, and interaction design. We argue that embedding cultural parameters into algorithmic color encoding is now essential to preserve identity, meaning, and expressive depth in contemporary fashion design.

4. Case study: Prada vs. Armani — a comparative evolution of chromatic language (1988–2024)

The pairing of Prada and Armani is intentional: within the same cultural arena, they embody paradigmatically divergent approaches to color (Pagano, and Di Dio Roccazzella, 2024; Santoro, 2006). Prada treats color as a narrative and experimental device; Armani pursues tonal and material coherence anchored in structural elegance (Evans, 2003).

To track this evolution, we identify five chronological phases for each brand (1988–2024), derived from a cross-analysis of Pantone codes, material palettes, runway archives (Prada and Armani), digital rendering workflows, and stylistic narratives (Di Corcia, 2019; Design Beauty, 2025; Farran Graves, 2023). Each phase maps to a distinct chromatic–technological paradigm, synthesized in Figure 3, which unifies three comparative tables into a single infographic for clarity and depth [1].

(1) Early phase (Prada: 1988–1993; Armani: 1980–1994)

Prada: austere palettes—graphite black, lead grey, matte military green—project a post-industrial, anti-luxury, quasi-militarized aesthetic with sharp tailoring and a structured femininity.

Armani: intense navy, sand beige, cool greys in combed wool and gabardine produce restrained, functional elegance with fluid silhouettes.

Tooling: color design remains analog (paper Pantone books, offset proofing, tactile fabric trials); digital processes are largely absent.

(2) Consolidation (Prada: 1994–2005; Armani: 1995–2005)

Prada: shifts to muted metallics—satin beige-pink, lilac, bronze—on organza and lustrous satin, articulating an “industrial delicacy.”

Armani: taupe velvet and powder-toned crêpe, desaturated and tactile, foreground introspection. Both embrace minimalism: Prada concept-driven; Armani material-driven.

Tooling: Photoshop gains ground for 2D chromatic visualization; physical verification on materials remains central.

(3) Aesthetic expansion (Prada: 2006–2013; Armani: 2006–2012)

Prada: techno violet, dusty blush, and vivid electric blue layered on vinyl and duchesse satin; an ironic, fluid visual language engaging with gender fluidity and citation.

Armani: an ethereal femininity via pearlescent chiffon, satin, and pastels emphasizing lightness and vertical flow.

Tooling: wider CAD adoption; Pantone-based color management is integrated into workflows—still largely visual, not immersive/material.

(4) Systematization (Prada: 2014–2020; Armani: 2013–2019)

Prada: synthetic materials (PVC, technical nylon) with fluorescents—acid orange, highlighter green, shocking pink—signal digital culture’s imprint: synthetic sheen and chromatic layering.

Armani: structured fabrics (velvet, knitwear) in saturated yet tempered tones, yielding a more theatrical, constructed presence.

Tooling: advanced control via CLO3D and Illustrator; nonetheless, digital render lags real material perception.

(5) Contemporary phase (Prada & Armani: 2021–2024)

Prada: brilliant yellow, copper-beige, and ice blue articulate a cyber, de-structured idiom that merges femininity with synthetic geometries and hybrid materials.

Armani: compact, contemplative schemes—electric blues and soft greens—realized in matte jersey and sand-washed organza, balancing classicism with digital hybridity (Beward, 2004).

Tooling: chromatic strategy becomes decisively software-mediated—CLO3D, Adobe Substance, Pantone Connect (Adobe, 2024)—and is increasingly shaped by immersive technologies and algorithmic simulations.

Tools such as CLO 3D, Adobe Substance, and Pantone Connect enable parametric color generation, material simulation, and cross-media color control.

Our analysis shows that, despite distinct visual languages, both brands converge on a strategic, identity-driven, and technologically informed use of color as a semiotic and cultural vector.

The Prada–Armani comparison also highlights the rising role of digital color encoding as a design and communication tool.

Overall, the study delineates two archetypes of chromatic evolution in the digital era: Prada articulates a postmodern, digitally inflected linguistic approach in which color operates as a narrative code; Armani sustains a tactile, structural continuity in which color embodies material elegance.

5. Toward a new logic of fashion design

From Munsell’s three-dimensional models and Albers’s interaction-of-color, through ICC color management, to generative AI (e.g., Midjourney, Pantone Connect AI), each stage has redefined the bond between color, medium, and meaning (Fig. 4). RGB and CMYK—originally devised for print and display—are now embedded in digital-fashion software to map color onto virtual textiles, 3D assets, and online interfaces, enabling controlled, cross-platform chromatic representation. The adoption of ICC profiles, wide-gamut spaces (Adobe RGB, Display P3), and AI-driven algorithms expands expressive range while spotlighting the gap between on-screen rendering and physical realization, thereby heightening color’s affective and symbolic charge (Albers, 2013).

Color Evolution and Material Strategy in PRADA (1988 – 2024)

Period	Chromatic Paradigm	Color Codes (Pantone)	Materials / Key Collections	Design Keywords	Suggested Visual Sources	Images
1988–1993 (Initial Phase)	<ul style="list-style-type: none"> Deep graphite black Metallic lead gray Matte military green 		<ul style="list-style-type: none"> Matte nylon, structured gabardine, rigid wool Urban military aesthetics, sharp cuts Runway: FW 1988, SS 1990, FW 1993 	<ul style="list-style-type: none"> Stark minimalism Military elegance Tactical anti-luxury 	Prada Runway Archive, FW/SS 1988–1993 Womenswear (official URLs)	https://www.prada.com/ww/en/pradasphere/fashion-shows/1989/womenswear.html
1994–2005 (Consolidation Phase)	<ul style="list-style-type: none"> Intense chestnut brown Saturated beige pink Desaturated lilac and bronze 		<ul style="list-style-type: none"> Organza and shiny velvet, beige satin Metallic details and soft industrial palettes Runway: FW 1996, SS 1997, FW 2001 	<ul style="list-style-type: none"> Industrial delicacy Functional neoromanticism Suspended elegance 	Prada Runway Archive, FW/SS 1994–2005 Womenswear (official URLs)	https://www.prada.com/ww/en/pradasphere/fashion-shows/1994/womenswear.html
2006–2013 (Aesthetic Expansion)	<ul style="list-style-type: none"> Saturated techno violet Powdered antique pink Bright electric blue 		<ul style="list-style-type: none"> Colored vinyl, duchess satin, shiny silk Chromatic contrasts, pop layering, oversized silhouettes Runway: FW 2007, SS 2008, SS 2011 	<ul style="list-style-type: none"> Pop irony Gender fluidity Visual citationism 	Prada Runway Archive, FW/SS 2005–2013 Womenswear (URL official)	https://www.prada.com/ww/en/pradasphere/fashion-shows/2006/womenswear.html
2014–2020 (Systematization)	<ul style="list-style-type: none"> Bright acid orange Highlighter green Fluorescent shocking pink 		<ul style="list-style-type: none"> Reflective PVC, technical textiles, rubber-effect nylon Synthetic transparency + chromatic layering Runway: SS 2014, FW 2018, FW 2019 	<ul style="list-style-type: none"> Digital futurism Chromatic stratification Synthetic brilliance 	Prada Runway Archive, FW/SS 2005–2013 Womenswear (official URLs)	https://www.prada.com/ww/en/pradasphere/fashion-shows/2014/womenswear.html
2021–2024 (Contemporary Phase)	<ul style="list-style-type: none"> Illuminating yellow Light copper beige Icy blue and sage 		<ul style="list-style-type: none"> Synthetic knits, shiny silk, printed organza Hybrid mixes and futuristic geometric cuts Runway: SS 2021, FW 2022, SS 2023, FW 2024 	<ul style="list-style-type: none"> Augmented materiality Deconstructed femininity Cybernetic elegance 	Prada Runway Archive, FW/SS 2014–2013 Womenswear (official URLs)	https://www.prada.com/ww/en/pradasphere/fashion-shows/2014/womenswear.html

Color Evolution and Material Strategy in ARMANI (1980 – 2024)

Period	Chromatic Paradigm	Color Codes (Pantone)	Materials / Key Collections	Design Keywords	Suggested Visual Sources	Images
1980–1994 (Initial Phase)	<ul style="list-style-type: none"> Deep navy blue Cool slate gray Light sand beige 		<ul style="list-style-type: none"> Combed wool, compact gray gabardine, flannel Technical cotton and matte silk Dark palette with matte finishes; utility-inspired looks Runway: FW 1982, SS 1985, FW 1992 	<ul style="list-style-type: none"> Stark minimalism Functional elegance Urban sobriety 	Giorgio Armani Runway Archive 1980–1994 (Getty Images Editorial – official links)	https://www.gettyimages.it/search/2/image?family=editorial&phrase=Armani%20runway%201980&sort=mostpopular
1995–2005 (Consolidation Phase)	<ul style="list-style-type: none"> Dark moka brown Medium anthracite gray Desaturated olive green 		<ul style="list-style-type: none"> Taupe velvet, powdery crêpe, washed cotton Desaturated tones and fluid draping Material neutrality: soft perception without visual contrast Runway: FW 1996, SS 1999, FW 2003 	<ul style="list-style-type: none"> Poetic neutrality Soft sensory aesthetics Introspective refinement 	Getty Images Editorial: Giorgio Armani Runway 1995–2005 (official URLs)	https://www.gettyimages.it/search/2/image?family=editorial&phrase=Armani%20runway%201995&sort=mostpopular
2006–2012 (Aesthetic Expansion)	<ul style="list-style-type: none"> Soft greenish gray Pale blush pink Dusty antique rose 		<ul style="list-style-type: none"> Green-gray georgette, pale satin, pearlescent chiffon Matte-gloss contrast in pastel tones Light volumes and vertical layering Runway: SS 2006, FW 2008, SS 2012 	<ul style="list-style-type: none"> Flowing femininity Impalpable tones Ethereal layering 	Getty Images Editorial: Giorgio Armani Runway 2006–2012 (official URLs)	https://www.gettyimages.it/search/2/image?family=editorial&phrase=Armani%20runway%202005&ort=mostpopular
2013–2019 (Systematization)	<ul style="list-style-type: none"> Muted olive green Vivid raspberry red Bright fuchsia 		<ul style="list-style-type: none"> Structured knits, technical velvet, luminous nylon Strong contrast between matte and gloss materials Geometric cuts and defined silhouettes Runway: FW 2015, SS 2017, FW 2018 	<ul style="list-style-type: none"> Visual precision Structured modernity Theatrical intensity 	Getty Images Editorial: Giorgio Armani Runway 2013–2019 (official URLs)	https://www.gettyimages.it/search/2/image?family=editorial&phrase=Armani%20runway%2013&ort=mostpopular
2021–2024 (Contemporary Phase)	<ul style="list-style-type: none"> Saturated electric blue Light copper beige Muted bluish green 		<ul style="list-style-type: none"> Sandy organza, matte jersey, micro-glossy silk Digital effects on natural-looking materials Chromatic layering in desaturated and muted tones Runway: SS 2021, FW 2022, SS 2023, FW 2024 	<ul style="list-style-type: none"> Digital stratification Hybrid elegance Sensory minimalism 	Getty Images Editorial: Giorgio Armani Runway 2021–2024 (official URLs)	https://www.gettyimages.it/search/2/image?family=editorial&phrase=Armani%20runway%2021&ort=mostpopular

Comparative Visual Language: PRADA vs ARMANI (Side-by-Side Overview)

Period	PRADA – Color + Language	ARMANI – Color + Language	Image (PRADA vs ARMANI)
1988–1993 / 1980–1994 (Initial Phase)	<ul style="list-style-type: none"> Graphite black, military green, lead gray Matte nylon, rigid cuts, anti-luxury aesthetic Harsh minimalism, military elegance 	<ul style="list-style-type: none"> Deep navy, slate gray, sand beige Combed wool, gabardine, compact flannel Functional elegance, urban sobriety 	Prada FW 1989 runway archive Armani 1980s–1990s collection via Getty Images (search link provided).
1994–2005 / 1995–2005 (Consolidation Phase)	<ul style="list-style-type: none"> Chestnut brown, satin beige pink, desaturated lilac Organza + glossy satin, industrial soft palettes Industrial delicacy, suspended elegance 	<ul style="list-style-type: none"> Moka brown, anthracite gray, soft olive green Powdery crêpe, taupe velvet Introspective refinement, soft sensory aesthetics 	Prada SS 2008 runway archive Armani SS 2006–2012 collection via Getty Images (search link provided).
2006–2013 / 2006–2012 (Aesthetic Expansion)	<ul style="list-style-type: none"> Techno violet, antique pink, electric blue Colored vinyl, duchess satin, chromatic layering Pop irony, gender fluidity, visual citationism 	<ul style="list-style-type: none"> Sage gray, pale blush pink, antique rose Pearlescent chiffon, satin Flowing femininity, ethereal tones 	Prada SS 2008 runway archive Armani SS 2006–2012 collection via Getty Images (search link provided).
2014–2020 / 2013–2019 (Systematization)	<ul style="list-style-type: none"> Acid orange, highlighter green, shocking pink Technical nylon, PVC, synthetic transparencies Digital futurism, chromatic stratification 	<ul style="list-style-type: none"> Muted olive green, raspberry red, fuchsia Structured knitwear, technical velvet, luminous nylon Visual precision, theatrical intensity 	Prada FW 2018 runway archive Armani FW 2015–2019 official images via Getty Images (search link provided)
2021–2024 (Contemporary Phase)	<ul style="list-style-type: none"> Illuminating yellow, copper beige, icy blue Printed silk, micro-glossy organza, hybrid materials Deconstructed femininity, cybernetic elegance 	<ul style="list-style-type: none"> Electric blue, copper beige, muted green Technical jersey, matte organza Digital layering, hybrid elegance 	Prada SS 2023 / FW 2024 runway archive Armani SS 2023–2024 images suggested via Getty Images and armani.com official show page (no reproduction used).

Fig. 3. Comparative evolution of color languages and material strategies in Prada and Armani (1980–2024).

Visual references are based on runway documentation from the Prada Official Archive (<https://www.prada.com/ww/en/pradasphere/fashion-shows.html>) and Armani collections as indexed via Getty Images Editorial Platform (<https://www.gettyimages.com/search/2/image?family=editorial&phrase=Armani%20runway>).

Historical Period	Color Theories / Technologies	Fields of Application	Chromatic Features	Key Examples / Case Studies	Images
1900-1920	Munsell (HVC); Ostwald (Harmony); Goethe (Perception)	Artistic education, color printing, textile design, visual fashion	Three-dimensional analysis; contrast; chromatic synthesis	A Color Notation (1905); Farbenfel (1916); Delaunay; Vogue graphics	
1920-1940	Itten (color wheel & contrast); Albers (interactive perception); Bauhaus (color pedagogy)	Interdisciplinary education, abstract art, graphic design, textile industry	Simultaneous contrasts; subjective harmonies; chromatic relationships	Itten, Kunst der Farbe; Albers' studies on color interaction; Bauhaus textiles; modernist posters	
1940-1960	ISCC-NBS (standard system); Albers (relational perception); Applied Munsell (USDA scale)	Industrial standardization, brand identity, color education, perceptual psychology	Chromatic codification; relational interaction; functional tone reduction	Interaction of Color (Albers, 1950s); ISCC-NBS schema (1955); Olivetti graphic identity; Yale teaching experiments	
1960-1980	Pantone Matching System (1963); Albers (didactic systematization); Corporate visual identity (IBM, Xerox)	Corporate identity, advertising, offset printing, editorial design, packaging	Corporate identity, publicità, stampa offset, design editoriale, packaging	Pantone Matching System; Interaction of Color (Albers, 1963); IBM visual identity; Olivetti & Braun visual systems	
1980-2000	Adobe RGB (1998); ICC Profile (1993); HTML Color Codes (W3C, 1996); Apple HIG	Computer graphics, web design, digital interfaces, photography, color management	Device-dependent color; ICC profile management; extended RGB range; hex encoding	Adobe Photoshop (1990); ICC v.3 (1993); W3C HTML 3.2; Apple Aqua UI (1999); Web-safe palette	
2000-2020	sRGB / Display P3 (Apple, 2015); Material Design (Google, 2014); CUD (Japan); AI-based palette generation	UI/UX design, mobile applications, augmented reality, digital branding, accessibility	Adaptive color; responsive contrast; perceptual inclusivity; algorithmic aesthetics	Google Material Color System; Apple P3 display; ColorBrewer; CUD system; Adobe Sensei palette (AI)	

Fig. 4. Evolution of Color Theories and Technologies in Design. Images generated via AI to simulate original references.

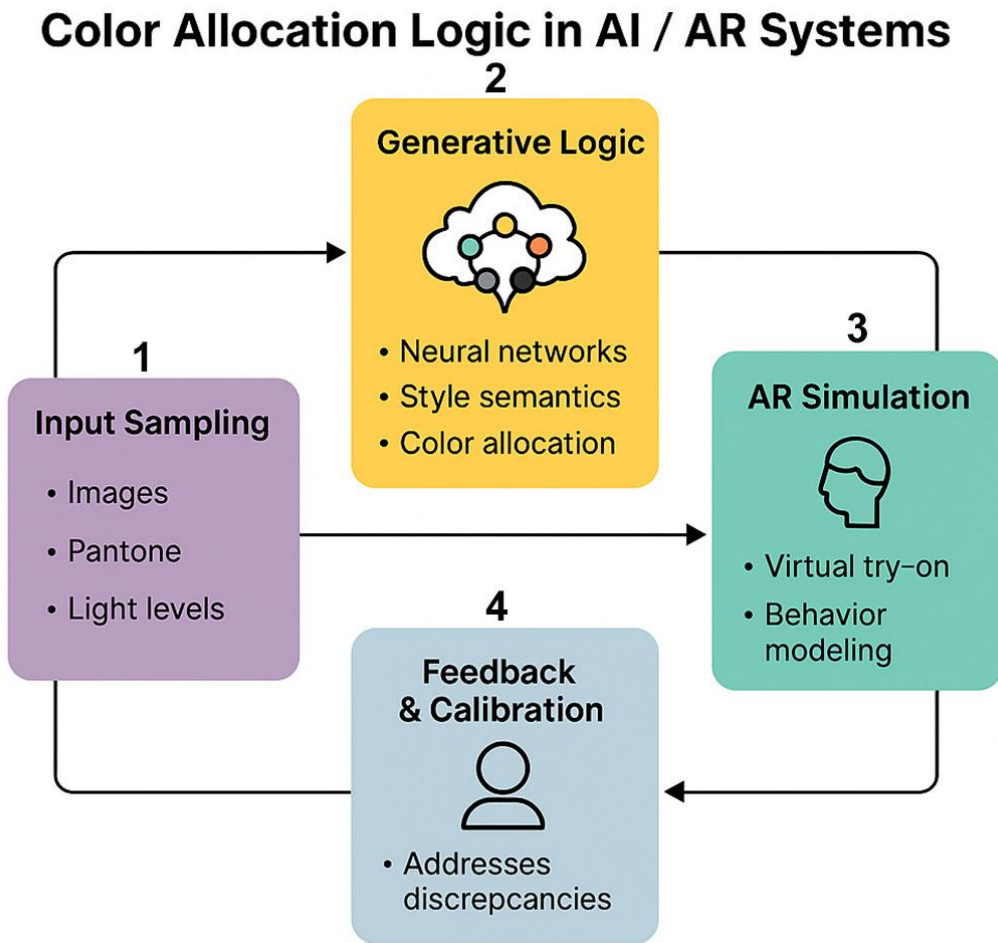


Fig. 5. Conceptual model of AI-based color allocation in digital fashion workflows: from initial input sampling to semantic generation and perceptual calibration.

In visual communication, color functions as an adaptive, programmable, cross-media language that preserves semantic and perceptual coherence across channels—from physical packaging to websites and social media. Universal codification (sRGB for the web, Pantone for print) and generative tools (e.g., Google Material Design’s responsive palettes; Adobe Sensei’s color optimization) help ensure consistency across touchpoints. The same hue can be reproduced on a product’s packaging, its online 3D visualization, and its social assets, delivering an integrated perceptual experience.

Within fashion, color operates as strategic grammar: building brand identity (e.g., Bottega Veneta green, Valentino red), carrying symbolic narratives (seasonal, emotion-driven palettes), and shaping behavior (e-commerce interfaces often leverage blue to foster trust) (Joung, 2023). No longer a mere surface, color is a semantic-technical device embedded in design workflows, orchestrating coherence between physical collections and their digital storytelling (Rocamora, 2009).

6. Future directions

6.1. Emerging innovations

In recent years, color design in fashion has consolidated into a divisible four-stage pipeline: (1) input capture, (2) generative color modeling, (3) perceptual simulation, and (4) feedback-driven calibration. Inputs include reference images, Pantone palettes, lighting conditions, and material properties (e.g., cotton, silk). Generative modeling uses AI systems—such as CLIP-based embeddings with Lab/RGB mappings—to allocate hues under semantic and technical constraints. AR/3D simulation tests colors on virtual garments and immersive sets, tracking ΔL , ΔC , and ΔH (lightness, chroma, and hue differences per CIEDE2000) (Itten, 1973) and rendering shifts. Feedback and calibration loop: feeds designer/user responses back into the model to reduce color error and improve cross-media coherence. Fig. 5 diagrams this flow (Input → Generative model → Simulation → Calibration).

Workflows based on visual presets or chromatic templates may bypass semantic generation, moving directly from input to simulation.

A representative case is the ZERO10 × Crosby Studios “interdimensional” pop-up in SoHo (New York), where responsive installations stage an immersive, multisensory chromatic experience across vision, sound, and bodily movement (Fig. 6).

AI-enabled color design also advances sustainability: predictive tools (e.g., Firefly, CLO3D) support virtual palette testing across fabrics and lighting scenarios,

reducing physical sampling—and thus material waste (cotton, silk) and pre-production energy use.

6.2. Cultural and technical challenges

Despite the promise of emerging color technologies, structural and cultural hurdles persist. The foremost is cross-device fidelity: color appearance varies substantially



Fig. 6. AI-generated representation of chromatic design in immersive retail and digital fashion environments. Inspired by the ZERO10 x Crosby Studios project. Images created using AI to avoid copyright issues

across displays, AR/VR environments, and print media, creating perceptual misalignments between designers and end users.

Beyond these technical incongruities, digital toolchains often overlook the cultural, symbolic, and ritual dimensions of chromatic codes—for example, red connotes prosperity in China but frequently signals danger in many Western contexts (Luzzatto, and Pompas, 2017).

To highlight the gap between digital encoding and material perception, we examined three tones recurrent in East Asian and Western collections (Chinese red, midnight blue, pearl gray), comparing their appearance on cotton and silk via synthetic visualizations under controlled conditions (standard illuminant D65, 2° standard observer, sRGB color space). The reported chromatic-difference values (ΔE_{00}), where provided, are indicative estimates derived from uniform render patches and do not replace spectrophotometric measurements. Fig. 7 qualitatively visualizes these perceptual differences for cotton and silk substrates.

These findings confirm that chromatic consistency cannot rely on digital codes alone; it requires control of material response and attention to cultural context. We therefore advocate adaptive color systems that integrate objective data (Lab, RGB, Pantone) with subjective parameters (emotional resonance, collective memory, tactile perception) (cf. Pantone, 2024).




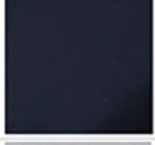



Color Sample	Color Code	Cotton (Visualized)	Silk (Visualized)	Perceptual Difference	Technical Notes
China Red				≈ 4.8 – Silk appears glossier and more reflective	Cotton: matte, uniform finish Silk: glossy reflections, higher saturation
Midnight Blue				≈ 3.2 – Silk is slightly brighter; cotton more opaque	Cotton: deep and matte Silk: rich blue tone with subtle reflections
Pearl Grey				≈ 5.0 – Silk is more reflective; cotton remains neutral	Cotton: stable, neutral tone Silk: pearlescent effect, enhanced brightness

Fig. 7. Qualitative comparison of color rendering on different materials (cotton vs. silk) using identical Pantone codes. Visualizations were generated by Fan T. under controlled conditions (standard illuminant D65, 2° observer, sRGB profile). The ΔE_{00} values shown are approximate perceptual estimates based on rendering patches, not derived from spectrophotometric instruments. Differences reflect material response (e.g., gloss, reflectance) under simulated conditions.

7. Conclusions

This study highlights that the co-evolution of digital tools and chromatic language, while enabling new paradigms of design in digital fashion—interactive, iterative, and customizable—has also increased the risk of aesthetic homogenization and a consequent erosion of direct sensory experience.

It is therefore hoped that future digital technologies in fashion will also acknowledge semantic and affective parameters, allowing color—within its cultural and perceptual dimensions—to guide the evolution of fashion design toward a new balance between human sensitivity and digital precision, between artistic intuition and parametric logic, between ritual memory and technological innovation.

8. Conflict of interest declaration

The authors declare no conflict of interest including financial, personal or other relationship with other people and organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, this work.

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11. Short biography of the authors

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Notes

[1] In Figure 3 for editorial reasons it was not possible to publish the figures representing the models of the two brands: Prada and Armani. Therefore, for each model mentioned we refer to a web page where the

corresponding image is visible. The date of last access, for this as for the indicated sites is 10/06/2025.

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