



Semantic colors: Using abstraction to create scalable design systems

Pratyush Tewari *

Human-Computer Interaction Institute, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, USA.

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Abstract

This article examines the foundational principles and systematic application of color within large-scale design systems through semantic abstraction. It details a methodology for leveraging color tokens to ensure scalability, maintainability, and consistent brand identity across diverse digital platforms. The system's core is a semantically structured color palette, categorized for specific UI purposes, including Brand, Text and Icon, Background, Border, and General UI elements. A critical aspect of this color system is its inherent commitment to accessibility, with color pairings designed to meet WCAG guidelines, ensuring usability for a wide range of users. The article explores how such a semantically designed and accessibility-conscious color system not only reinforces brand identity but also streamlines the design and development process, leading to more coherent and inclusive user experiences. This approach offers a robust model for developing comprehensive color strategies in complex product ecosystems.

Keywords: Semantic color systems; Design tokens; Accessibility integration; Scalable design; Cross-platform consistency

1. Introduction

Color is a fundamental visual design element, playing a critical role in establishing brand identity, guiding user interaction, and ensuring accessibility across digital platforms. As digital ecosystems grow in complexity and scale, organizations face mounting challenges in maintaining consistency while adapting to diverse contexts and requirements. Traditional approaches to color management, often characterized by direct application of hexadecimal values or RGB codes, prove increasingly inadequate in modern design systems that span multiple products, platforms, and user contexts.

The evolution of digital interfaces has significantly intensified the need for structured color management approaches. Research into enterprise architecture frameworks reveals that semantic abstraction principles, when applied to design elements such as color, substantially improve interoperability across diverse technical environments [1]. These interoperability frameworks demonstrate how abstraction layers create essential separation between implementation details and functional requirements, enabling more sustainable scaling of visual systems across organizational boundaries. Introducing semantically structured naming conventions creates a shared vocabulary that bridges communication gaps between design and development teams, particularly in cross-functional environments where specialization often creates a siloed understanding of visual components [1].

This article presents a systematic approach to color implementation through semantic abstraction, drawing on a comprehensive design system case study. By examining the principles, structure, and application of a semantically organized color system, the research demonstrates how abstraction creates resilience and adaptability while maintaining brand cohesion. Contemporary semantic color systems employ structured taxonomies that categorize visual elements according to their functional purpose rather than visual characteristics, creating a robust foundation

* Corresponding author: Pratyush Tewari

for complex interface development. This methodology addresses technical challenges in color management while aligning with contemporary needs for accessibility compliance and responsive design.

The semantic color system outlined in this research provides a framework that bridges design intent with technical implementation, offering valuable insights for both practitioners and researchers in the field of design systems. The approach draws conceptual parallels to biological systems research, where cell signaling pathways demonstrate how consistent patterns can maintain systemic integrity despite environmental variations [2]. As cellular mechanisms employ standardized signaling protocols to maintain homeostasis across diverse conditions, semantic color systems establish consistent patterns that adapt to various contexts while preserving essential brand characteristics [2]. As organizations navigate the complexities of multi-platform experiences, such structured approaches to color management become increasingly essential to sustainable design practices.

2. Theoretical Framework of Semantic Colour Systems

2.1. Defining Semantic Color Abstraction

Semantic color abstraction represents a paradigm shift from direct color application to a structured, meaning-based approach to color implementation. At its core, this methodology establishes a layer of abstraction between the visual expression of color (typically represented as hexadecimal values, RGB, or HSL codes) and its functional application within interfaces. This abstraction is achieved through a system of tokens, named entities that encapsulate both visual properties and functional intent. Research into visual communication systems demonstrates that semantic structuring aligns with established cognitive frameworks for information processing, particularly in complex visual environments [3].

The semantic dimension of this approach derives from naming conventions that reflect the purpose, context, and relationships of colors rather than their visual characteristics. For example, rather than referencing a specific shade of blue by its technical color value, a semantic system might define it as "primary-action" or "brand-primary," immediately communicating its role within the interface. Studies of user experience design patterns suggest that such functional naming conventions significantly enhance cross-disciplinary collaboration between designers and developers [3].

2.2. Historical Context and Evolution

The evolution of semantic color systems can be traced through several phases of digital design maturity. Early web and application development typically employed direct color implementation, with specific color values embedded directly in code or defined in simple style sheets. As design systems emerged in the mid-2000s, organizations developed more sophisticated approaches to visual consistency, including rudimentary color palettes and style guides. Historical analysis of color management systems reveals a progressive shift from device-dependent approaches toward more abstract, semantically structured frameworks, paralleling the increasing complexity of digital ecosystems [4].

The contemporary approach to semantic color abstraction has roots in object-oriented design principles and systematic design methodologies that gained prominence in the 2010s. Research in color appearance modeling indicates that successful abstraction frameworks must account for perceptual consistency and functional meaning across diverse viewing conditions [4]. Modern semantic color systems represent a maturation of these practices, emphasizing scalability, maintainability, and cross-platform consistency.

2.3. Theoretical Advantages of Abstraction

From a theoretical perspective, semantic color abstraction offers several significant advantages. Cognitive efficiency emerges as users work with meaningful abstractions rather than low-level color values, with studies of design practices demonstrating reduced decision fatigue in complex projects [3]. The separation of concerns between brand identity and functional application allows each aspect to evolve independently, creating crucial flexibility in evolving digital environments. Systematic approaches to color relationships promote consistency across interfaces, with research suggesting enhanced user recognition and reduced learning curves [3]. Finally, adaptive resilience enables design systems to accommodate changing requirements with minimal disruption, as modifications can be implemented at the token level rather than throughout the codebase. Studies of color management evolution demonstrate that abstract models provide superior adaptation capabilities across diverse viewing environments and technologies [4].

Table 1 Theoretical Advantages of Semantic Color Systems [3,4]

Advantage	Benefit
Cognitive Efficiency	Reduced decision fatigue
Separation of Concerns	Independent evolution of brand and function
Systematic Relationships	Enhanced user recognition
Adaptive Resilience	Minimal disruption during changes
Cross-Platform Consistency	Superior adaptation across environments

3. Structure and Categorization of Semantic Color Palettes

3.1. Primary Categorization Frameworks

Effective semantic color systems require thoughtful organizational structures that balance comprehensiveness with usability. Modern design systems exemplify a multi-tiered categorization approach that organizes colors according to their functional roles within interfaces. This framework typically includes primary categories such as brand colors, text and icon colors, background colors, border colors, and general UI colors. Research into psychological responses to color demonstrates that these functional categorizations align with how users naturally perceive and interpret color within digital environments, enhancing usability and emotional response [5].

Brand colors embody the core identity of the organization or product, while text and icon colors are optimized for information conveyance through typography and iconography. Background colors serve as foundational elements for interface composition, with border colors defining boundaries and structural elements. General UI colors are designated for specific interface elements and states. Studies of semantic color associations indicate that these categorical distinctions reflect cognitive patterns in how users process visual information, reinforcing the value of functionally structured color systems [5].

3.2. Hierarchical Token Structures

Within each primary category, semantic color systems implement hierarchical structures that reflect both the specificity of application and the relationships between colors. This hierarchy manifests in naming conventions following organized patterns that include category, element, property, state, and variant components. This structured approach enables precise targeting while maintaining systematic relationships between tokens. Research into adaptive environments demonstrates that hierarchical structures support more efficient implementation across diverse contexts, allowing for systematic adaptation to various user needs and technical requirements [6].

The hierarchical nature of these structures facilitates inheritance and override patterns crucial for maintaining consistency and flexibility. Base tokens establish fundamental color relationships, while specialized tokens address edge cases and specific interaction states. Studies of adaptive systems reveal that hierarchical frameworks significantly enhance the scalability and maintainability of complex color implementations [6].

3.3. Context-Responsive Variations

Sophisticated semantic color systems account for various contexts in which colors appear, including mode variations (light/dark), accessibility variations (WCAG compliance), and platform-specific adaptations. Research into adaptive multimodal systems shows that contextual responsiveness is essential for maintaining consistent user experiences across diverse environments and usage scenarios [6]. These variations are implemented through parallel token structures that maintain semantic relationships while adapting visual expression to specific contexts, ensuring that functional intent remains consistent even as visual representation adapts. Studies of adaptive interfaces demonstrate that semantically structured color systems provide a robust foundation for responsive design, supporting consistent experiences despite varying environmental conditions, user preferences, and accessibility requirements [6].

Table 2 Structure and Categorization of Semantic Color Palettes [5,6]

Category	Purpose
Brand Colors	Core identity expression
Text/Icon Colors	Information conveyance
Background Colors	Interface foundation
Border Colors	Visual structure definition
UI Colors	Interactive state indication

4. Implementation and Technical Architecture

4.1. Token-Based Implementation Methods

The technical implementation of a semantic color system requires a robust architecture that bridges design intent with development practice. Modern implementations typically employ a token-based approach using various technical frameworks. Design tokens serve as machine-readable files (typically JSON or YAML) that function as a single source of truth for color values, often with transformation capabilities to generate platform-specific code. Technical approaches to scalable systems emphasize the importance of centralized definitions that can be distributed across diverse environments, mirroring the architectural principles found in effective token implementations [7].

CSS custom properties are frequently leveraged in web implementations to instantiate the token system, enabling dynamic updates and theme switching without code changes. Native platform variables maintain the semantic structure in mobile and desktop applications through platform-specific variable systems. Design tool integration ensures consistency between design and development environments by synchronizing implementation and design assets. Professional analyses of token-based systems highlight how these integration methods significantly streamline workflow between designers and developers while reducing inconsistencies in implementation [8].

4.2. Managing Color Relationships and Dependencies

Effective semantic color systems carefully manage the relationships between colors to ensure visual harmony and functional clarity. Tonal relationships involve systematic variations in lightness and saturation that create perceptual connections between related colors. Functional dependencies establish logical connections between colors used in related contexts, such as the relationship between a button's background color and hover state. Inheritance patterns create hierarchical relationships where specialized tokens inherit properties from more general tokens unless explicitly overridden. Studies of scalable technical architectures demonstrate how these relationship patterns mirror effective dependency management in other complex systems, with clearly defined hierarchies and inheritance models proving essential for maintainability [7].

4.3. Scaling and Maintenance Strategies

As design systems grow in complexity and scope, maintenance becomes a critical concern. Versioning protocols establish clear processes for introducing, deprecating, and updating color tokens, often aligned with the broader design system versioning strategy. Adoption tracking involves monitoring token usage across products to identify obsolete tokens and assess the impact of potential changes. Automated testing systematically validates color relationships, particularly for accessibility compliance and brand alignment. Documentation and governance encompass comprehensive guidelines that articulate the purpose, usage, and limitations of each color token. Examinations of token-based design systems emphasize how these maintenance strategies determine long-term success, with governance processes as the foundation for sustainable evolution and consistent implementation [8]. The principles of scalable system architecture highlight how centralized management combined with automated distribution mechanisms creates robust and adaptable color systems that can evolve while maintaining coherence [7].

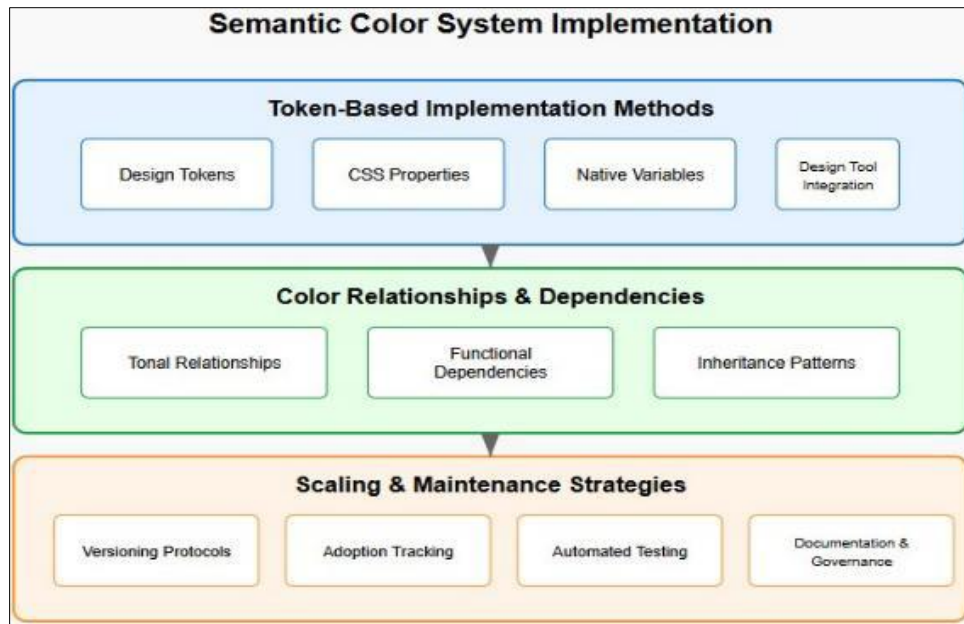


Figure 1 Semantic Color System Implementation Architecture [7,8]

5. Accessibility and Inclusive Design Integration

5.1. WCAG Compliance Through Semantic Structure

A significant advantage of semantic color systems is their capacity to systematically address accessibility requirements. The Web Content Accessibility Guidelines (WCAG) establish specific contrast ratios between text and background colors to ensure readability for users with visual impairments. Systematic literature reviews of digital accessibility implementation reveal that structured approaches to color management significantly improve compliance rates across digital products [9]. Well-designed semantic color systems incorporate accessibility requirements directly into their structure through several key mechanisms.

Paired token relationships establish explicit connections between foreground and background colors, ensuring that commonly used combinations meet contrast requirements by design. Conformance level indicators within token naming or metadata specify the WCAG conformance level for specific color combinations, creating clear standards for implementation. Automated validation integrates contrast checking within the token system, often as part of the build process, to prevent accessibility regressions. Research indicates that such structured approaches to digital accessibility provide more sustainable compliance than ad-hoc remediation strategies [9].

5.2. Addressing Diverse User Needs

Beyond basic contrast requirements, comprehensive semantic color systems address a broader range of accessibility considerations to serve diverse user populations. Color blindness accommodations involve careful selection of color palettes that remain distinguishable for users with various forms of color vision deficiency. High contrast modes provide alternative token mappings that dramatically increase contrast for users who require enhanced visibility. Reduced motion considerations address color animations or transitions by accounting for user preferences regarding motion sensitivity. Studies of inclusive design practices demonstrate that moving beyond mere compliance to thoughtful accommodation of diverse needs creates more universally usable interfaces [10].

These accommodations are typically implemented through specialized token sets or context-specific overrides that maintain the semantic structure while adapting visual presentation to diverse user needs. By embedding accessibility considerations directly into the semantic framework, design systems can ensure that adaptations maintain functional clarity and brand consistency across different user requirements [10].

5.3. Testing and Validation Frameworks

Ensuring ongoing accessibility compliance requires systematic testing and validation processes that evolve alongside the design system. Automated testing tools integrate color contrast analyzers and accessibility validators within the design and development workflow. Manual review protocols establish structured processes for human evaluation of color implementations, particularly for edge cases and complex interfaces. User testing with diverse participants validates that theoretical compliance translates to practical usability for people with various visual impairments. Literature reviews of accessibility practices emphasize combining automated tools with human evaluation to achieve comprehensive validation [9].

By incorporating these validation mechanisms into the semantic color system's governance structure, organizations can maintain accessibility compliance even as the system evolves. Inclusive design approaches suggest that incorporating accessibility from the foundation of a design system, rather than as an afterthought, creates more resilient and usable products for all users [10].

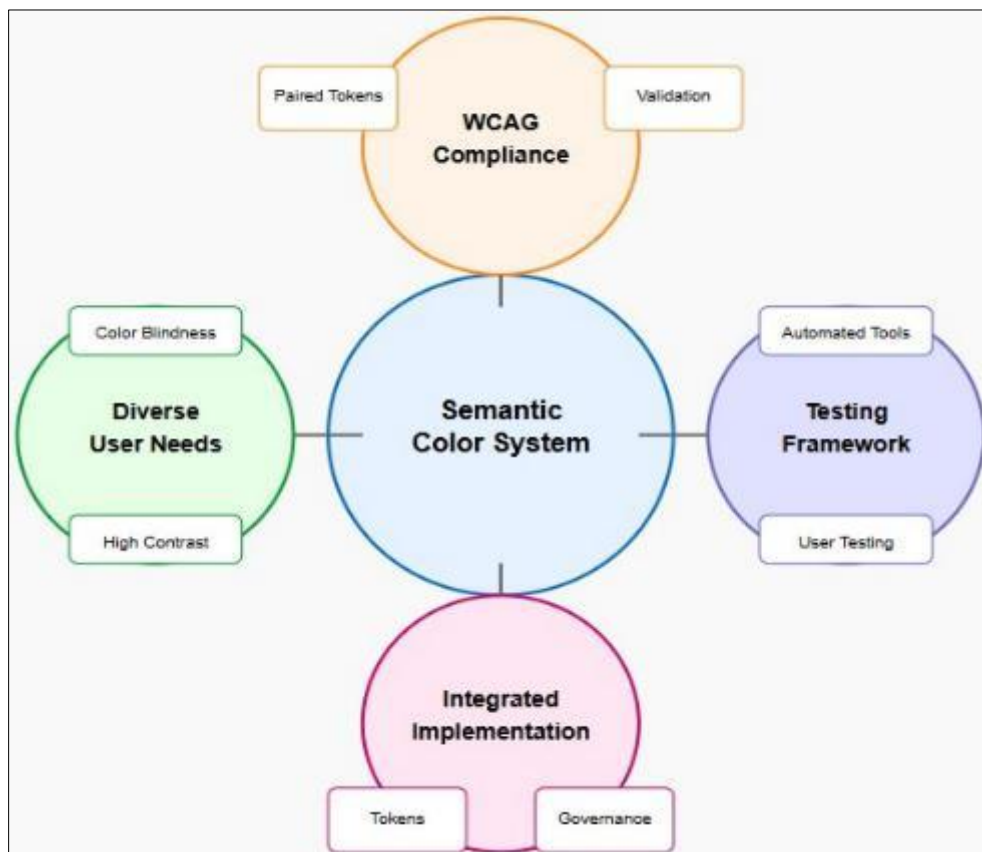


Figure 2 Hub Model of Accessibility Integration in Semantic Color Systems [9,10]

6. Conclusion

The exploration of semantic color abstraction within design systems reveals a transformative approach to managing visual consistency and functional coherence across complex digital ecosystems. Semantically structured color systems offer profound advantages in scalability, maintainability, and accessibility compliance compared to traditional color management approaches. The power of abstraction lies in its ability to separate brand identity from functional application, creating resilience against evolving design requirements and technical contexts. The hierarchical organization of color tokens, categorized by functional roles, provides precision and flexibility, reducing cognitive load while ensuring systematic consistency. By integrating accessibility considerations directly into the semantic structure, technical requirements become an inherent characteristic rather than an afterthought. As digital ecosystems continue expanding in complexity, the principles of semantic color abstraction offer a robust foundation for managing visual design at scale, enabling organizations to deliver more coherent, inclusive, and adaptable user experiences across digital touchpoints.

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