Data-Driven Future Visions: Color Design Foresight

Jingyuan Wang[a] and Xia Li[b] *

{ [a]wjyuan@bupt.edu.cn , [b]lixia1@bupt.edu.cn* }

Beijing University of Posts and Telecommunications, Haidian District, Beijing, China

Abstract: The rapidly evolving technological landscape has continuously expanded the horizons of color research, brimming with future uncertainties. Hence, it is crucial to consider various complex factors and drive the development of color design from multiple dimensions. Prior studies on future visions lacked the practical integration of data-driven approaches with workshops. This paper utilizes extensive data from social platforms for co-creation and combines workshops to gather weak signal data for future visions. This study brings methodological innovation to future vision generation, establishing a comprehensive research process, and designing a two-dimensional visual model for visualizing these visions.

Keywords: future visions; data-driven; color; Futures Triangle; future thinking

1 Introduction

Although humans have had thousands of years of history in the application of color, color has long played a role primarily in display functions, and its use as an aesthetic tool came relatively late.[1] In recent times, with the discovery of the interactive patterns between color and people's lives and aesthetic practices, color design has emerged as an important art form for enhancing artistic expression and expressing thoughts and emotions. Almost every race, religion, and culture has a clear view of the importance and application of color, using it to differentiate and attribute meaning to objects.[2] Throughout the 20th century, technology became a pivotal driver in extending color's domain amidst numerous changes. In the 21st century, advancements in technology have subtly reshaped the core ties between color, humans, objects, and nature. Color science, fortified by prolonged research and practice, has evolved into a scientifically grounded, specialized discipline rooted in principles like perspective, artistic anatomy, optics, and psychology. This field now spans diverse applications, from art and design to industrial color, color imaging, capture, display, and printing. Additionally, these applications include color design, color and architecture, color and education, color and culture, color coding, color management, color processing, and related work in computer graphics color synthesis.

Because color research encompasses various aspects of people's social lives, understanding color has transcended its physical and technical dimensions. Every innovation in color research and application might potentially become a new opportunity for humanity's future. Simultaneously, looking towards the future, the demand for diversity in color design will continue to grow, leading to more conflicts due to numerous humanistic and environmental factors intertwined with the application of color. Therefore, applying methods from future

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studies can help predict more potential futures.[3] Additionally, approaching color development and design from a future-thinking perspective, including considerations of color materials, cognitive and cultural dimensions, as well as its impact on human and computer interactions and communication, holds significant importance in shaping a better future that involves color participation. The Futures Triangle model serves as a valuable tool in envisioning potential future scenarios, with weak signals playing a pivotal role in shaping these outcomes and acting as precursors to emerging trends and societal shifts. Despite their importance, identifying weak signals relies heavily on qualitative research approaches that may be limited in scale; thus, futurists advocate for integrating more intuitive and inclusive methods to bolster the creation of comprehensive future design visions, including those related to color design.

Based on the aforementioned background, the main contributions of this study are as follows: firstly, the use of data-driven methods to rapidly collect co-creation data from online platforms; secondly, the proposal of a new two-dimensional visualization model for generating future visions, combined with the theory of de-futurization; thirdly, the design of a complete process for constructing a future vision, incorporating the two-dimensional model; fourthly, the systematic introduction of a data-driven approach to future design, applied in the field of color design research. The research process is planned using Future Vision Generating Toolkits.[4] The specific research process includes designing the generation methods, constructing the visualization model, collecting data, analyzing the data, constructing network graphs, conducting network graph analysis, organizing workshops, and presenting the results, as shown in Figure 1.

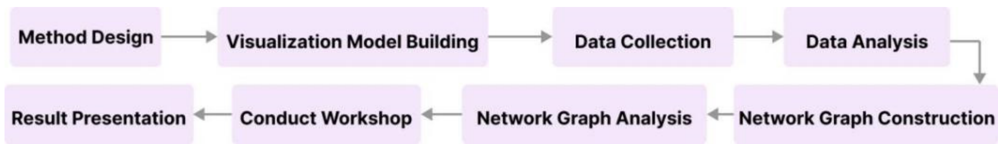

Figure 1: Research Process of this Study

2 Related Work

2.1 Approaches to Guiding Future Design

The Futures Triangle is one of the methods used to map different future scenarios, first proposed by Inayatullah in the book "Questioning the Future".[5] The value of the Futures Triangle lies in considering the interactions between its three dimensions, i.e., pulls, pushes, and weights. The underlying epistemological stance of this method is that the future is challenged, rethought, and created, aligning with the critical approach in future studies.[6]

Design is always about the future. In the field of design, Tony Fry first introduced the concept of futurization in Design Ethics in 1999.[7] In a broader sense, futurization is the process of establishing a diverse set of future possibilities, while de-futurization is the process of selecting a future (or set of futures) through certain filtering methods and developing plans to move closer to the chosen future. Zhiyong Fu, in his research, developed an approach that simultaneously ensures exploration of future possibilities and feasibility in implementation. He proposed a two-dimensional design coordinate system that includes a timeline and futurization/ de-futurization.[8]. Additionally, Design fiction uses design to tell stories, where the design prototype is based on imaginative realities, and the narrative or story is the designer's reflection and speculation. When designers engage stakeholders in envisioning the future, "context" becomes a primary design outcome, shifting away from the "technology-driven" and "business-oriented" approaches of other product design methods. As a result, design recommendations for various aspects of society can be examined from a first-person subjective perspective. Zhiyong Fu combines design thinking with future thinking and proposes four parts of the Future Vision Generation Toolkit: Generate Future Chronicles, Generate future vision from the perspective of an event node, Vision shaping creates, and Co-create.[5]

While numerous tool models guide future design theoretically, there's a scarcity of practical experimentation and a lack of consideration for visual expression in future design.

2.2 Apply Social Media Data for Foresight

The application of social media data is one of the methods used to predict future trends.[9] Social media contains a vast amount of stakeholders' comments, opinions, and feedback on their needs. Research has shown that analyzing or predicting projects using social media data can provide valuable insights for investment.[10] Moreover, key weak signals in the Futures Triangle can also be obtained from data on social media platforms, and some scholars have already applied this in practice.[11] Therefore, social media data is reliable for predicting weak signals in the future. Semantic network analysis can identify social perception trends of an event or industry on social media.[12] The higher the centrality, the more connections the word represented by the node has with other words in the network. The advantage of collecting data from social media is that they encompass various stakeholders.[13]

Therefore, through semantic network analysis, researchers can examine the most critical vocabulary in social networks of different event stakeholders to gain insights into their social viewpoints and trends. Applying the analysis results to research on future landscapes can offer robust support for exploring weak signals.

2.3 Color Design and its Application Fields

Color design is involved in all aspects of people's social life. In the field of art and design, color design focuses on the harmonious use of colors for aesthetic projects by designers or artists. Color in fashion design was developed by the school of Bauhaus and has been very enriching and interesting.[14] From the mid-20th century to the present, the unique color methods of Color Field painters have influenced art and applied design. Before digital design emerged, many designers were influenced by Bauhaus color courses, which provided training in color mixing and application techniques.[15] In environmental design, color can be used for care design in places such as hospitals, schools, and nursing homes. An appropriate application of color can create a friendly and welcoming atmosphere that is comfortable for all.[16] Additionally, in the design of transportation hubs, various safety elements need to be carefully considered, with particular attention given to color aspects by designers.[17]

In the era of digitization, researchers have made significant efforts in the field of color computation. For example, researchers applied k-means clustering to acquire color categories from samples of pixels in natural images, using a minimum-distance criterion among members of the same color category. In another work, probabilistic latent semantic analysis (PLSA) was used to learn color names from a collection of images obtained from search engines.[18]

In recent times, people have become aware of the issue of sustainable development in relation to Earth's resources, and the sustainable development of the color field has also become a new topic. The environmental characteristics of colorants (dyes and pigments) encompass topics pertaining to the impact of such compoundson human health and biota. In recent years, fungi have emerged among the prominent, eco-friendly sources of natural pigments. Easy processing, fast growth in cheap media, and weather-independent growth make them an excellent alternative to natural pigments.[19]

In conclusion, whether viewed from a technological or social perspective, every facet of color encompasses a myriad of complex factors associated with both human-nature relationships and the constraints imposed by human history, society, culture, and technology. Therefore, this paper aims to focus on methodologies and tools for future design, exploring how color, in the development of human society, should respond to the viewpoints and resonance sought by people in the future, ultimately generating future landscapes that hold valuable insights.

3 Data-Driven Visualization for Future Visions Generation

3.1 Process of Constructing Future Visions through Visualization

In the previous literature review on Approaches to Guiding Future Design, many approaches were mentioned. According to Zhiyong Fu's Future Visions Generation Toolkit, it should include four components: Generate Future Chronicles, Generate future visions from the perspective of an event node, Visions shaping creates, and Co-create. This paper's process of constructing future visions, combined with data-driven requirements, proposes a new system flow, as shown in Figure 2.

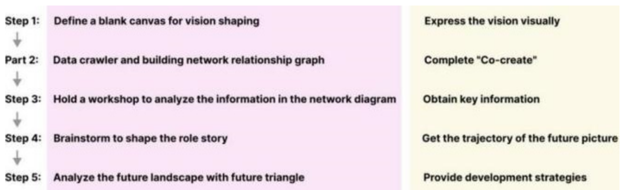

Figure 2: Process for Visualizing Future visions

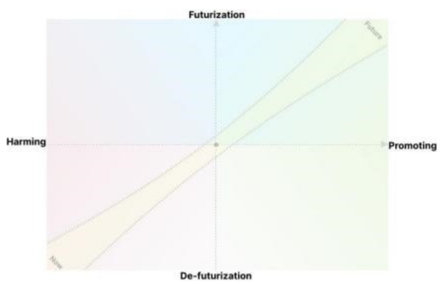

Figure 3: Canvas

3.2 Two-dimensional Visualization Future visions Generation Model

In related studies, it has been indicated that combining design thinking with future thinking can better support future design work. Therefore, this paper introduces a de-futurization design thinking into the model and incorporates futurization and de- futurization as indicators on a blank canvas. Additionally, Philipp Koebe's Scenario Analysis, which considers both promoting and harming futures, has also inspired the design of this model.[20] Thus, this paper presents a Visualized Two-dimensional Trajectory Drawing Canvas, as shown in Figure 3. The canvas is designed to support the visualization of future visions, with defined axes and quadrants. Finally, the canvas, along with the future trajectories created through brainstorming by the participants, constitutes the two-dimensional visualization future visions model in this paper. The future trajectory created by the participants on this canvas is hereinafter referred to as the "2D Future Trajectory".

Canvas divided by futurization/de-futurization and Promotion/Harm creates four quadrants. Quadrant 1 denotes high futurization and positive impact. Following quadrants represent varying degrees of futurization and harm, ending with quadrant 4 for low futurization but promotion. Participants start from current societal issues (quadrant 3) and progress toward a positive future (quadrant 4). Canvas depicts an ideal progression from bottom left to top right. Colors aid comprehension: red warns of harm, blue symbolizes futurization, and green indicates sustainability and health.

The two-dimensional visualization future visions generation model consists of the following elements: Visualized Two-dimensional Trajectory Drawing Canvas (including the two axes of "Futurization and De-futurization" and "Promoting and Harming," the reference line for the perfect development from present to future, and the four quadrants of different colors), future event nodes conceived by the participants, future trajectories formed by connecting the event nodes, and visual explanations.

3.3 Data Analysis

Social media platforms store many user opinions and views, providing rich data sources for studying the future development of intelligent color design in the social domain. RED (XiaoHongshu) is a community-based platform. On RED, researchers can find numerous notes, images, and videos on topics such as color and design. Users on RED come from various backgrounds, and their shared content covers a wide range of fields and perspectives, providing researchers with diverse data sources to collect comprehensive data related to color design and application. In this study, a web crawler program was used to crawl the text content under the "color" tag topic on RED. The top 520 notes were crawled based on popularity. The data includes user ID, RED note links, number of likes, and analyzed text data. The analyzed text data set includes titles, main content, top comment 1 and top comment 2, totaling 2080 entries.

In this study, data cleaning was conducted in the preprocessing stage. Invalid notes related to unnecessary advertising products were removed, resulting in a total of 2035 valid text data entries. The author then performed word segmentation on these valid text data using a word segmentation tool based on Lucene SmartChineseAnalyzer, extracting words and conducting word frequency statistics on the segmented results. The author selected 582 nouns with word frequency ranging from 10 to 1315. These nouns were then subjected to manual synonym merging and selection, removing proper nouns, product names, and other words that were not relevant to the research. Finally, 60 nouns were selected as “label words”for further research.

With the popularization of graph applications, graph deep learning techniques have gradually gained favor among data mining teams. These methods help analysts gain insights into the complex relationship features hidden in the data.[21] A semantic relationship network, sometimes referred to as a co-occurrence network, is used to analyze text. A co-occurrence network visualizes the potential relationships between words. If two words appear together in RED notes, we consider them to have a co-occurrence relationship. The number of times these two words appear in RED notes represents the weight of the co-occurrence relationship. For example, A and B are posts with different keywords. Referring to the text analysis method,[22] the weight between them can be expressed as $\mathrm{Wab} = \mathrm{count}(\mathrm{A} \cdot \mathrm{B})$, where $\mathrm{count}(\cdot)$ donates the number of times the same words appear in A and B.

A co-occurrence analysis yielded 1129 inter-group relationships. After establishing the relationships, one column was used as the source and the other column as the target for network visualization. Gephi (version 0.10.1) was used to create a network and generate a network relationship graph. By inputting the visualization results and the target into Gephi, the visual representation of the network can be obtained.[23] The network relationship graph generated from the 60 label words in this study is shown in Figure 4.

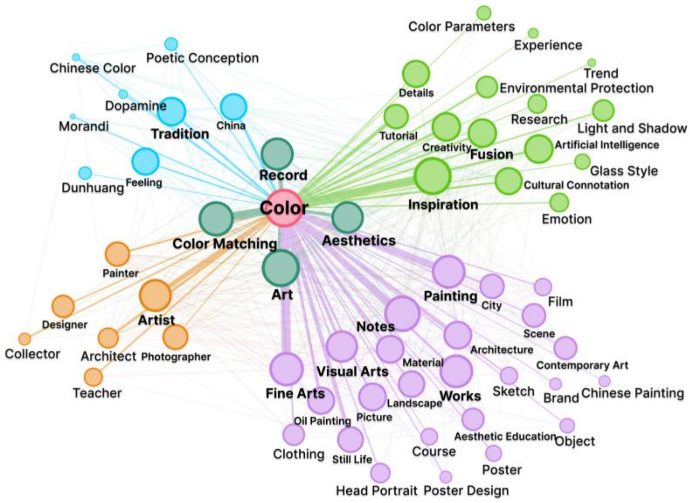

Figure 4: A Network Diagram with "Color"

The author conducted eigenvector centrality and clustering analysis based on the semantic network constructed during the data preparation phase. A node with a higher eigenvector centrality is connected to more nodes, indicating its greater importance in the network. The larger the circle of a node, the higher the importance of the corresponding label word. Eigenvector centrality analysis was performed using Gephi software (version 0.10.1). The eigenvector centrality analysis method was used to explore key keywords in the network and gain valuable insights. Eigenvector centrality represents the sum of connections between a node and other nodes.[24] Specifically, given a node V_i, the eigenvector centrality of the central node V_i is defined using the centralities of its neighboring nodes:

$$C_e(V_i) = \frac{1}{\lambda} \sum_{i=1}^{N} A_{ij} \cdot C_e(V_j)$$

Where Ce is the eigenvector of the adjacency matrix A, and λis the characteristic value.

In addition, in this study, based on the eigenvector centrality of each node and their meanings and contextual content, the author classified and clustered the 60 nouns. The "Color" term has an eigenvector centrality of 1, positioned in the center of the relationship graph and has the most connections, as shown in Figure 4. The four closest words to "Color" also have relatively high eigenvector centrality values. Next, as shown in Figure 5, the four corners of this diagram are categorized as follows: the top-right corner with a green node represents user-expressed demands or desires, defined as "Descriptor of requirements". The top-left corner represents aesthetic preference factors, defined as "Preference of styles". The bottom-left corner represents various stakeholders, defined as "Stakeholders". The bottom-right corner represents existing products, items, or color application industries, defined as "Existing products or applications of color". The clustered network diagram provides clearer information, helping to reflect the opinions and attention of social media platform users towards color-related industries.

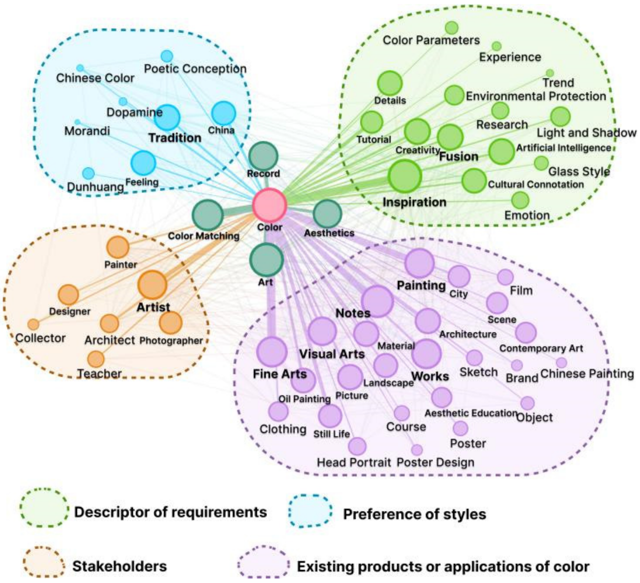

Figure 5: Node Clustering

3.4 Generate Alternative Futures Visions

After completing the construction of the network relationships, the author initiated a workshop and posed the core question: What does everyone envision for the future of color? Undergraduate and graduate students, as well as teachers, were recruited to conduct research and analysis on the semantically significant nodes with high eigenvector centrality in the network relationship diagram. A high eigenvector centrality value indicates the importance of the node in the network system. During the workshop discussions, the participants showed a general interest in the nodes belonging to the "Descriptor of requirements" category. After brainstorming and organizing the discussions, the focus of the future ideas was centered around three key words: Environmental Protection, Creativity, and Artificial Intelligence. The eigenvector centrality values for these three words are shown in Table 1, indicating their importance in the computed results.

Table 1: Eigenvector Centrality of Three Key Words

No.	Lable Words	Eigenvector Centrality
1	Creativity	0.83608315
2	Artificial Intelligence	0.824695499
3	Environmental Protection	0.692400557

After analyzing three partial network relationship diagrams, participants formed random groups based on their interests and received a Visualized Two-dimensional Trajectory Drawing Canvas. The experiment began with seven participants divided into three groups.

In the first group, two participants referred to the network relationship diagram centered around "Environmental Protection". They then proceeded to create a fictional narrative based on this data. The visualized content can be seen in Figure 6.

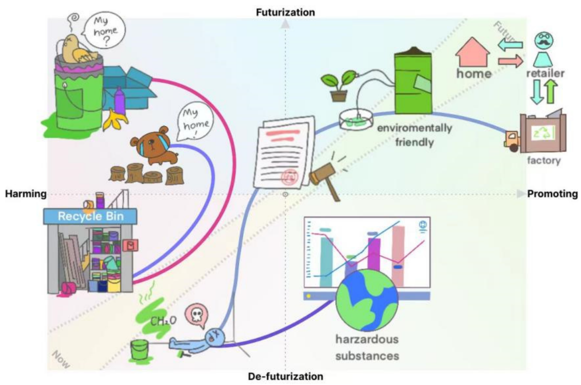

Figure 6: 2D Future Trajectory of the First Group

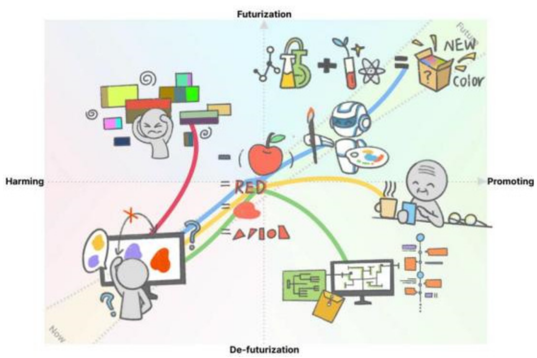

Figure 7: 2D Future Trajectory of the Second Group

Future Narrative 1: “Currently, there's a surge in human-made products like paint pigments, architectural coatings, and artificial dyes, lacking an effective waste disposal system. These artificial colors pose a threat to the natural color system. As society progresses, incessant extraction of natural resources for dyes may harm animal habitats, disrupting their homes in the not-so-distant future. Placing this event node in the lower part of the second quadrant on the canvas signifies its imminent impact. Moreover, animals like birds of prey and those with intricate visual systems rely on color for specific mating and feeding functions. Artificial colors in their habitats could confuse their vision, disrupting their normal survival behaviors, posing a significant threat to species conservation.”

Future Narrative 2: “I've recently heard about cases where construction materials triggered cancer due to their toxicity. Hence, I'm more concerned about the health impact of color materials in eco-friendly colors. To address this, governmental bodies or social organizations should test and disclose the toxicity of paint colors, promoting environmental awareness to the public. Achievable steps, so I positioned this event node in the fourth quadrant. Furthermore, if the ruling class prioritizes environmental color issues with involvement from political, economic, and legal experts, a supervisory mechanism can regulate the market. Eventually, natural and microbial dyes will replace toxic compounds as their market diminishes. With scientific advancements, I aspire to recycle all color waste, an idealized future, positioned at the canvas's apex of 'Futurization' and 'Promoting'.”

The three participants of the second group referred to a network relationship diagram centered around ”AI”and obtained network information from public participation to create fictional stories. The visualized content can be seen in Figure 7.

Future Narrative 3: “In the past two years, AI painting has become very popular. Like many users on RED, I have been trying AI creativity. However, there are still barriers in communication between users and computers in the field of intelligent generation. Therefore, the starting point of the trajectory on our drawing board is the ineffective communication between humans and machines. If we do not emphasize the effectiveness of human-machine communication, it is very easy to have problems of color misuse and abuse, leading to a future of color aesthetic pollution. I placed this event node in the second quadrant.”

Future Narrative 4: “In an intelligent color matching system, if we want to achieve barrier-free communication between humans and machines, we need to quantify the emotional factors of colors. Human visual perception and psychological emotions need to be expressed through the quantification of color parameters. With the advancement of technology, color design applications will be primarily handled by computers or robots, and it may give rise to some well-known robot artists. As technology continues to advance, in an increasingly intelligent era, intelligent systems may engage in computation and creation, giving birth to new colors different from traditional ones. The world of colors will become more and more vibrant.”

Future Narrative 5: “I haven't pondered the distant future, yet I've identified color-related issues worth tackling. With better technology, I believe color predictions for designers can become more accurate. While color trends have been forecasted lately, public acceptance isn't widespread, and global favorites often fail to resonate with the color preferences of diverse ethnicities and regions. Thus, the color prediction industry must focus on and promote this facet; I've categorized this concern in quadrant four. Moreover, the importance of color consideration cannot be overlooked. Designing colors for varied groups—like seniors, children, and healthcare settings—should prioritize user-centricity and cater to their unique requirements. Conceivably, in the near term, intelligent color computations could automatically adapt to different group needs, enhancing design efficiency.”

The third group, consisting of two participants, referred to a network relationship diagram centered around 'creativity' to gather network information from public engagement for fictional storytelling. The visual content can be seen in Figure 8.

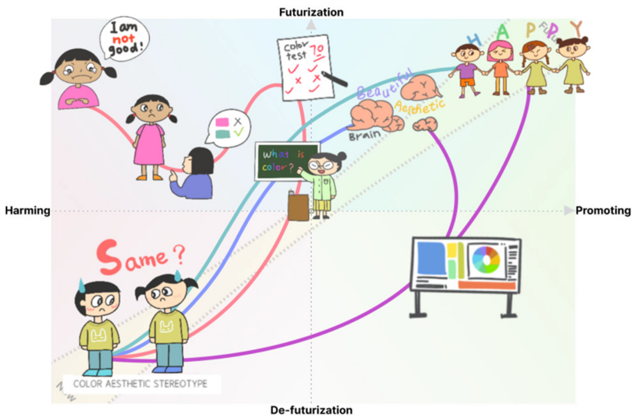

Figure 8: 2D Future Trajectory of the Third Group

Future Narrative 6: “In the era of information, 'homogenization' stands as a stark contradiction. Whether on social media, e-commerce platforms, or in daily life, the prevalence of repetitive content and color combinations feels mundane. Using the scenario of 'wearing identical outfits' symbolizes this issue. To truly break free from this homogenization cocoon, educators become pivotal. Public needs an expanded cultural knowledge and heightened aesthetic sense. By spreading and promoting color knowledge, matching techniques, and uplifting awareness, we aim to liberate public perception of beauty. This leads to an aesthetic harmony in colors and nurtures cultural reverence towards them.”

Future Narrative 7: “If color becomes a foundational course, inevitable tests and assessments might face student resistance. Once the mindset of exam-oriented learning sets in, the original intent of fostering aesthetics fades. Colors might then encounter increased labeling and ossification. For instance, rigid beliefs like pink clothes not suiting darker skin could persist, hindering diverse color development. I hope for everyone to embrace the freedom of colors.”

4 Results

4.1 Stakeholder Analysis

From the data obtained from social media platforms, stakeholders active within the content of online media have been identified. Subsequently, within the role stories of the seminar, the author also discovered some stakeholders hidden in future narratives, such as microbiologists, materials researchers, legal researchers, and animal researchers.

4.2 Futures Triangle

After screening the data obtained from web crawling on social media platforms, there were initially 60 nodes, which reduced to 53 nodes after removing 7 stakeholders. When incorporating the descriptions provided by workshop participants, weak signals for the Futures Triangle were derived.

We believe that the nodes within the "Descriptor of requirements" area of the network relationship diagram largely express user needs and visions. Besides the obvious vocabulary terms like "Light and Shadow" or "Glass Style" represent some demands for product design. For instance, "Glass Style" represents a hazy and mysterious visual effect, primarily used in the appearance design of technological products such as interfaces for AR and VR products, due to its modern, concise, and stylish appeal. Therefore, the appearance of such terms demonstrates a departure from traditional color concepts, indicating that people are increasingly influenced by technology, leading to the popularity of technologically-driven color designs.

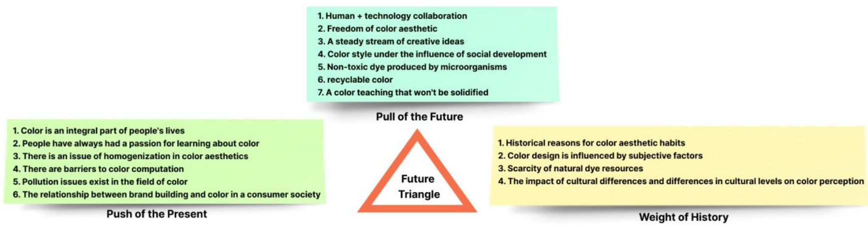

Figure 9: 3 Dimensions of Future Color Design

On the other hand, the nodes within the "Preference of styles" area primarily reflect people's aesthetic preferences influenced by historical or existing factors. Apart from "Dunhuang" and "Chinese Colors," there are terms like "Dopamine" and "Morandi." The creation of the dopamine color scheme is related to people's perception and response to colors, igniting feelings of pleasure and excitement. The emergence of Morandi colors is mainly related to Morandi's artistic style and aesthetic concepts, presenting a calm and harmonious artistic style that can alleviate inner anxiety and unease. The author has summarized the weak signals extracted from the network relationship diagram and role stories to form the Futures Triangle of color design， as shown in Figure 9.

4.3 Strategies for Future of Color Design

Based on the Futures Triangle presenting the futures visions, we can determine which futures we do not want to face and devise strategic plans to move closer to the better future we desire. This paper summarizes the future color development strategies from three critical points.

Sustainability:

1. Material Production: Reevaluate harmful color materials; increase research investment in eco-friendly materials for various pigments, coatings, and dyes; employ renewable materials and bio-dyes.

2. Waste Management: Focus on categorizing color waste for recycling; encourage designers in color-oriented disassembly and reassembly designs from waste.

3. Environmentally Friendly: Promote harmonious color designs for the environment; emphasize the impact of human-induced color pollution on other animal behaviors.

Computability:

1. Human-Machine Communication: Strengthen semantic mapping between color and computing, facilitating computers' understanding of human color demands during human-machine collaboration.

2. Color Management: Continuously upgrade digital color storage and management methods to adapt to higher productivity intelligent systems.

3. Prediction Systems: Optimize color prediction computation methods to swiftly capture and apply complex color combinations and trends.

4. Emotional Care: In the development of intelligent colors, do not neglect capturing color emotions and emphasize humane concerns, such as preferences among children, the elderly, color-blind, and color-weak populations.

Diversity:

1. Cultural Emphasis: Enrich the connotation of color designs in native cultures, focusing on cross-cultural color fusion designs.

2. Breaking Labels: Encourage designers to infuse more vitality into color designs, embracing non-standard colors and creating more possibilities.

3. Aesthetic Awareness: Provide more opportunities and resources for color learning to enhance public aesthetic consciousness fundamentally. Promote cultural exchange and understanding, creating a richer, shared color experience for future society.

5 Conclusions

In this exploration of the future trajectory of the color theme, the visualized futures visions doesn't solely incorporate opinions from numerous users on social media platforms; it's a collaborative creation. It's also revealed potential dynamics of the future through brainstorming in workshops. Beyond facilitating pivotal events, there are potential adverse futures such as color pollution and the solidification of color aesthetics, highlighting the challenges faced by this field.

Looking ahead, the ongoing technological explosions have resulted in color chaos. However, color design is poised to emerge from this chaos and achieve a rebalancing of colors. A preferable future for colors will be one where everyone feels positively engaged. Traditional methods of gathering Futures Triangle data were limited by small sample sizes. In this study, we integrated a substantial amount of data from social networks using web crawlers. Additionally, this paper's proposed data-driven visualized futures visions generation method includes a complete construction process for the futures visions and a two-dimensional visual model. Subsequently, this method was employed to explore the futures visions of color design, confirming the feasibility of this approach.

While this study utilized de-futurization theories in design, it didn't specifically outline the process of future retrospection, nor did it discuss short-term implementation solutions for some envisioned events. Futures studies will delve deeper into these areas, aiming to further enhance the generation method of visualized futures visions.

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