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Algorithmic Analysis of Color Combinations Principle in Game Concept Art

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Abstract

Numerous investigations have been conducted on the topic of color combinations, with a focus on generating color palettes to depict the patterns inherent in such combinations. These color palettes have proven to be immensely valuable in the realm of visual design. Our research also concerns color combinations; however, our approach involves the utilization of algorithms to demarcate visual center and non-visual center regions within game concept art. By adopting an artist's perspective, this research delves into the comprehension of color combinations. In light of our prior investigations, we summarize the colors associated with the visual and non-visual centers, using color segmentation, and subsequently compute the respective color proportions in these two areas for conclusive purposes. Furthermore, we ascertain the hue, saturation, and lightness characteristics of each color, thereby discerning the underlying laws of color combinations within the game concept art. The objective of this research paper is to provide digital artists with the means to produce superior and expeditious artworks that align with contemporary aesthetics.

1. Introduction

The exploration of color combinations has long held significance within the domains of painting and visual design. Colors possess three-dimensional attributes encompassing hue, saturation, and brightness, causing the combination of colors a complex undertaking. Moreover, the aesthetics governing color combinations have evolved. Notably, several analogous investigations on color combinations have been conducted in various areas. For instance, Jahanian [1] conducted research analyzing color combinations and proportions in the context of logo design. Differing from this research, our study primarily concentrates on game concept design. Scholars have endeavored to comprehend color through varied perspectives, seeking novel methodologies and patterns for color combinations. For example, Yamazaki's investigation [2] investigated the interplay between Kansei and color, while Hu's study [3] combined familial factors and rhythm span to establish a novel approach to color selection. Distinct from visual arts such as pictures and photographs, game concept art holds utmost significance within the gaming industry [4]. In game concept art, colors serve multiple purposes such as defining a unique style, drawing viewers' attention, and making a contrast. Many ideas and results garnered from prior research on color combinations can be applied to game concept design drawings. However, the treatment of color in game concept design and painting differs considerably between the visual center and the non-visual center, an aspect often overlooked in previous studies. In our prior investigation, we employed a module to distinguish between visual center areas and non-visual center areas in 2D game concept art. Approaching the subject from an artist's perspective, this study will meticulously analyze color transformations and combination patterns within the distinct areas of the visual center and non-visual center. Consequently, the application of color combinations in the field of game design will be further nuanced. We anticipate that the findings will enhance the dexterity of game artists in employing color during the drawing process.

Our research target are game concept art that follow the contemporary aesthetics. Contemporary aesthetics refers to the branch of philosophy and art criticism that explores and analyzes the nature, principles, and theories of beauty and artistic expression in the context of the present time or contemporary culture. Aesthetics, in general, is concerned with understanding what makes something beautiful or aesthetically pleasing and how we perceive and appreciate art and beauty. It takes into account the influence of the current cultural, social, political, and technological factors on our understanding of aesthetics. Given the rapid advancements in technology, contemporary aesthetics also explores how digital media, virtual reality, and other technological innovations have reshaped the ways in which art is created, experienced, and understood.

Our study differs from previous studies of color combinations in three main points. The first point is that our study's focus differs from that of photographs and visual designs. Game concept artwork diverges from photographs and graphic design in its utilization of colors, which are employed in bolder and more complex ways. This is especially evident in game scene designs, where game concept art incorporates color contrasts and subtle color changes.

The second point is that our research concentrates on the visual center. In previous research, color information usually from the entire image was analyzed and summarized. However, for game concept designers, understanding the visual center is a crucial design method. The methods and rules of using colors in the visual center and in the non-visual center area will be very different. This is a unique feature not found in other similar studies, such as those focused on photographs or visual designs.

The third point emphasizes the importance of color proportion, which is often a neglected aspect in similar color combination studies. The percentage of color can significantly alter the overall visual impact of an image and can also affect the intensity of color contrasts.

2. Related work

2.1 Color combination palette

Color combinations belong to similar research across various fields, each with its own particular focus of research. However, the underlying objective remains constant, namely, the quest to uncover patterns in color combinations that can enhance the efficacy of artists or AI systems in the area of design and painting.

Several research pertaining to color combinations and visual centers serve as illustrative examples.

Firstly, within the domain of visual design, a study has concentrated on investigating the relationship between color combinations on magazine covers and the thematic content of the magazines, as shown in Figure 1[1]. This investigation delves into the consistency between color and content. To achieve this, the study used the LDA-duel approach to categorize magazine keywords into 12 distinct themes. Subsequently, the colors used on the covers were separated into 10 color palettes.

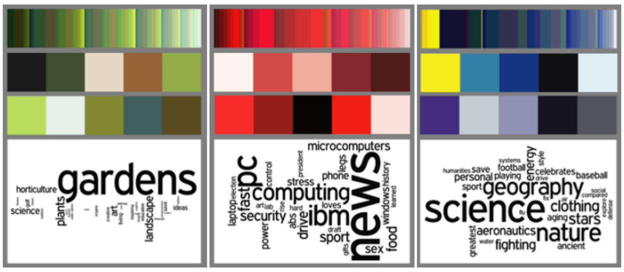

Figure 1. Matching of Color Combinations and Text Content [1]

This research similar to our own investigation; however, it focuses on a different domain. Our study places greater emphasis on elucidating the disparities between visual and non-visual centers, as well as highlighting the significance of color proportions.

Similar investigations have been conducted in prior research, such as Decarlo's study [5], wherein strokes and area segmentation were performed based on photo colors, subsequently exploring the impact of objects on saliency.

In recent investigations, novel methodologies have been discovered to explore the field of color palette analysis. To illustrate, Chang's seminal study [6] introduced an interactive tool was designed to allow non-professionals to fill the color photographs using a color palette generator. Furthermore, Kumar's research [7] endeavored to elucidate color palette extraction through the application of the k-means clustering algorithm, thereby presenting an innovative approach for the color palettes.

However, our study differs from their research. Firstly, our focus centers on game concept artwork, which possesses a comprehensive and more exaggerated color and shape. Secondly, our investigation places particular emphasis on the analysis of color combinations, with a specific focus on discerning the disparities between the visual and non-visual centers.

2.2 Visual Interest

Prior investigations using eye-tracking methodologies have also explored the concept of visual centers. For instance, as shown in Figure 2, which represents one of the earlier tests of visual centers. In this particular study, participants were invited to view multiple traditional paintings, while their eye movements were recorded using an eye-tracking system [8]. Subsequently, participants were finished a questionnaire aimed at elucidating the factors that influenced their observations.

The present study was conducted by a questionnaire-based approach to investigate the factors associated with the visual center, although it should be noted that the majority of participants were not professional artists. Consequently, the influence of color, a significant determinant of the visual center, is often ignored by the general audience.

The visual center constitutes a subjectively determined area, influenced by multiple variables, including the content, coloration, and compositional attributes within an image. Analogous to the practices employed by traditional artwork and Impressionists in the realm of traditional paintings, game concept artists use diverse strategies aimed at guiding the viewer's attention. This involves deliberately directing the viewer's attention towards a specific area of the artwork, thus delineating the visual center in the game concept art.

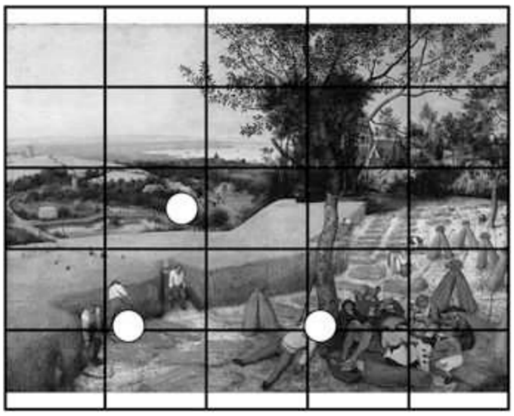

Figure 2. An Example of Visual Interest Research [6]

2.3 Fine Art Instruction

The next example applies the findings to the realm of fine art instruction [9]. This investigation utilizes digital technology to analyze patterns in color combinations, subsequently integrating these patterns into painting education. Through the utilization of digital tools, students acquire an understanding of color interactions and learn to manipulate the relationships between colors. For art students in training, it is crucial to understand the theoretical underpinnings of color. The authors outline their experiences teaching color concepts using various digital tools and elucidate how the results are effectively applied to traditional painting instruction. It is evident that historically, color approaches relied heavily on the subjective experiences and practices of artists. However, the advent of technology has facilitated digital tools that enhance our comprehension of color. This advancement enables the formless attribute of color to possess value and enables a more objective analysis.

At the same time, Stepanova's research also illustrates the importance of color utilization in traditional artwork. Stepanova's work emphasizes that the proportion of colors used and the variety of colors in a traditional artwork play a vital role in determining the artwork's value or impact [10]. In other words, the balance between different colors and the range of colors employed can greatly influence the overall aesthetic and emotional appeal of a traditional painting or drawing. The proportion of colors is often neglected in the study of digital paintings, as mentioned in 2.1.

2.4 AI painting

In recent times, there has been a surge in the development of AI painting systems, exemplified by the disco diffusion approach [11]. Disco diffusion represents a nascent AI painting system that rapidly generates game concept art based on input keywords, demonstrating proficiency in image generation for game scenes. Furthermore, it can emulate the style of specific artists through machine learning techniques. Notably, this type of AI system offers the advantage of producing a substantial number of results within a short time and at a relatively low cost. Artists can leverage such AI systems to expedite the completion of preliminary drafts. However, upon evaluating the generated outcomes, it becomes apparent that further enhancements are required in terms of visual center processing and color combinations. Professional artists are still necessary to select the most available results for refinement, and there is space for improvement in color and composition as well. In future plans, we hope to combine the data obtained from this experiment with AI.

3. Proposed method

Our study follows the structure in Figure 3, comprising multiple sequential steps. In the initial step, we used image segmentation to separate the local region within the image, specifically differentiating the visual center and the non-visual center regions. A comprehensive explanation of this step can be found in our prior study [12]. In the second step, we divided the different color intervals according to the HSV (hue, saturation, value) values of the colors into black, white, grey, red, orange, yellow, green, cyan, blue, and violet.

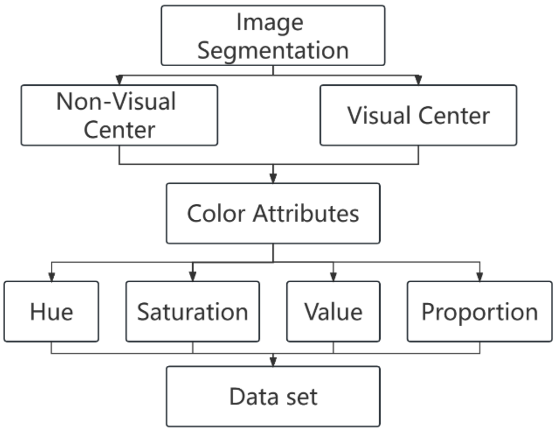

Figure 3. Framework of method

Our research methodology is focused on the artistic perspective, whereby an algorithmic framework is employed to emulate the artistic design process for an artwork. The HSV color space has been found to be most conducive to traditional color mixing methods including a wide range of materials such as oil painting, watercolor painting, and other conventional materials. Such methods commonly involve the utilization of three primary colors (red, blue, yellow) to create a range of hues, adjust color saturation using complementary colors, and change the brightness by using black and white colors. That is the reason we chose HSV as the color space. By individually scrutinizing the proportions of each color interval within each local region, we sought the patterns in color usage. These outcomes were compiled into a table, observing the percentage of different color intervals. This analysis validated the visual center's consistency, as established in the preceding image segmentation step. Finally, we comprehensively analyzed the data presented in the table to draw definitive conclusions regarding the basic color combination patterns.

4. Experimental method

4.1 Visual center detection

In our initial investigation, a clear differentiation was established between the visual centers and non-visual centers in the game concept art. As illustrated in Figure 4, we partitioned the concept art into 16 distinct regions, denoted as local regions. This approach draws upon the research conducted by Wang [13], which suggests that using a 4x4 grid segmentation represents an efficient method for scene recognition. Each of these segmented regions includes both the visual center local region and the non-visual center local region.

At the start of the experiment, we explored various segmentation methods, including 2*2, 3*3, 4*4, 5*5, and 6*6. The 2*2 and 3*3 segmentation methods cause the local regions too large, making it challenging to determine the location of the visual center. Conversely, segmentation sizes of 5*5 or more than 5*5 cause the local regions that were excessively small, hindering the comprehensive analysis of color changes within each local region. In conjunction with Wang's research survey, we chose 4*4 segmentation approach to conduct the experiment.

Figure4. Segmentation of game concept art

4.2 HSV Color interval

We determined the specific values for each color interval. The intervals for specific colors are not consistent in different studies.

	black	gray	white	red1	red2	orange
Hmin	0	0	0	0	156	11
Hmax	180	180	180	10	180	25
Smin	0	0	0	43	43	43
Smax	255	43	30	255	255	255
Vmin	0	46	221	46	46	46
Vmax	46	220	255	255	255	255

	yellow	green	cyans	blue	purples
Hmin	26	35	78	100	125
Hmax	34	77	99	124	155
Smin	43	43	43	43	43
Smax	255	255	255	255	255
Vmin	46	46	46	46	46
Vmax	255	255	255	255	255

Figure 5. The range of color HSV values

Figure 5 is the experimentally calculated vague range. This value includes the maximum and minimum values of Hue, saturation, and lightness. There are many color spaces in the current perception of color, such as Lab, HSV, RGB, and YIQ [14]. For our specific objectives, we have chosen to utilize the HSV color model due to its resemblance to the traditional approach to color in painting. In traditional painting, a set of saturation and lightness base colors is initially available, and these colors are blended in varying proportions to create a wide range of colors. This process of color mixing involves the use of contrasting colors to reduce purity and brightness, black and white to adjust brightness and decrease saturation, and the addition of the initial single color to enhance saturation. These fundamental color grading methods align with the principles of the HSV color space. Our method is designed based on the HSV color space that aims to analyze color in game concept art from the perspective of a designer. Zhang's research [15] highlights the variations in color space, including RGB, HSV, LAB, YIQ, and Opponent. While the RGB color model is the fastest to employ, it is also the least accurate, whereas the HSV color model proves to be more precise [15]. Cui [16] also suggests that the HSV color space accurately represents the human perception of color when compared to other color models, demonstrating a strong correlation with the subjective understanding of color by human eyes. So, we chose to use HSV as our color space. We are converting the color values into color labels based on the HSV range. Then, as shown in figure 6, we count the number of pixels in each color label. Finally, we convert it into a histogram.

4.3 Data Analysis

The algorithm was employed for the computation of the proportion of visually similar color pixels within the central visual area, as well as the proportion of analogous colors within the non-visual area, for each distinct local region. The resulting outcomes were subsequently recorded in the table, as shown in Figure 6. A total of one hundred instances of game concept art were selected as samples, sourced from the esteemed game concept art community, Artstation [17]. This platform is renowned for hosting an extensive collection of original artworks from prominent games. Each individual sample was segmented into sixteen local regions, amounting to a cumulative analysis of 1600 local regions. Through this comprehensive examination, distinctive patterns in color combinations were discerned and documented.

16 Local Region

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
black	0	0	0	0.26	0	0	0.74	0.35	0.44	1.22	1.24	3.32	0.29	0.33	0.14	1.5
gray	97.13	90.67	96.22	96.17	97.22	85.33	58.18	70.37	20.54	31.09	36.18	32.3	0.34	0.59	4.16	0.06
white	0.07	0	0.14	0	0.15	0.11	0.9	0.02	0	0	0	0		0	0	0
red1	0	0	0.07	0.33	0.06	0.09	12.68	10.61	0.27	3.32	6.37	0.09	0	0	0	0
red2	0	0	0	0.1	0.06	3.58	5.43	1.96	0.01	0.37	0.74	0.01	0	0	0	0
orange	0	0.01	1.27	0.36	2.2	9.62	9.37	11.12	0.64	4.63	1.71	3.4	0	0	0	0
yellow	0	0.02	0.04	0.03	0.16	0.17	0.45	0	0	0.06	0.01	0.06	0	0	0	0
green	0.02	0.05	0.02	0	0.04	0.01	0.01	0	0	0.01	0	0.01	1.74	1.87	0.02	0.02
cyans	2.92	10.33	2.1	2.02	0.04	1.45	0.15	0.01	4.1	3.18	0.69	0.45	7.7	14.53	0.49	0.52
blue	0.11	0.12	0.88	1.07	0.53	0	12.44	6.01	74.73	57.71	54.08	58.46	87.35	79.88	94.84	95.3
purples	0	0	0	0.26	0	0.69	1.77	1.22	2.08		2.02	4.19	2.71	3.02	0.7	2.92

Figure 6. An example of color combination data, and we represent the proportion in Figure 7 by using histogram

As shown in Figure 6, we set a range of HSV values for each color by the label of the color which we mentioned in section 4.2, and counted the proportion of each color in each local region separately by python code. For instance, the orange in the first local region is shown as 0, which means that there is no any orange color present in that local region.

Figure 7. An example of color combination data

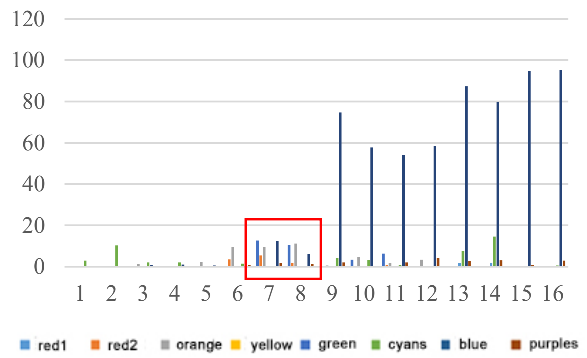

Figure 8. An example of color combination data

In order to analyze the data, we convert the data to the histogram. Figure 7 illustrates the distribution of colors within individual local regions. The x-axis pertains to each local region, while the y-axis represents the proportion of black, white, gray, and other colors present within each region. The red line signifies the visual center area in Figure 7 and Figure 8. Notably, the histograms employed depict two distinct approaches to color analysis. As shown in Figure 7, it encompasses black, white, and gray colors, while the Figure 8 histogram excludes them. Evidently, the color transitions within the visual center area exhibit greater intensity. The non-visual center area is almost occupied by a single color. Lastly, a comprehensive synthesis is conducted, encompassing the observed patterns of color combinations.

5. Result and Discussion

Following the data analysis conducted in Section 4.3, the initial step involved the categorization of the entire sample into two distinct groups. The first group shows a positive correlation between color alterations and the visual center. In contrast, the second group encompassed images wherein no such correlation was evident between color changes and the visual center. Subsequently, an analysis was undertaken to discern patterns within these two groups. Notably, we divided the first group into two categories based on their characteristics. The first category shows significant color changes within the visual center. The second category is the majority of the image characterized by black, white, and gray tones, and the visual center represents at least 50% of the color distribution. Consequently, the entirety of the samples was categorized into three distinct typologies.

Our findings indicate the existence of three preeminent color combinations prevalent within the game concept art. To categorize these combinations, we designate them as follows: "typical," "balanced," and "monochrome."

5.1 Typical

The first color combination, denoted as "typical," accounts for 36.61% in the samples. Figure 9 is one of the examples. This particular combination is distinguished by a pronounced contrast in color combinations within the visual center, while the non-visual center primarily comprises analogous colors. Figure 10 visually depicts the distribution of gray, accounting for 51.03% of the image, and blue, accounting for 38.96% of the overall composition. Those gray and blue belong to the non-visual center area. Notably, the visual center region exhibits a profusion of diverse color combinations. In these findings, it is frequently observed that the visual center prominently features complementary colors of lower contrast. Complementary colors are pairs of colors that, when placed next to each other, create a strong visual contrast. It will produce a neutral color like gray or white when they mix. Complementary colors are positioned directly opposite each other on the color wheel. Understanding complementary colors can be helpful when making color choices in design and art, as they can be used to create eye-catching and harmonious color schemes. Lower contrast complementary colors are colors that are 120 degrees apart on the color wheel, like yellow and blue.

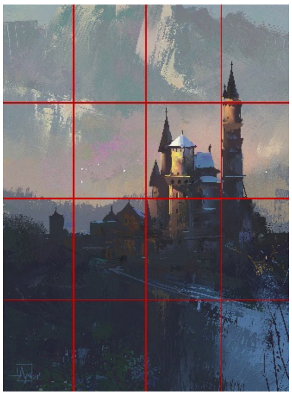

Figure 9. The data of typical color combinations. [18]

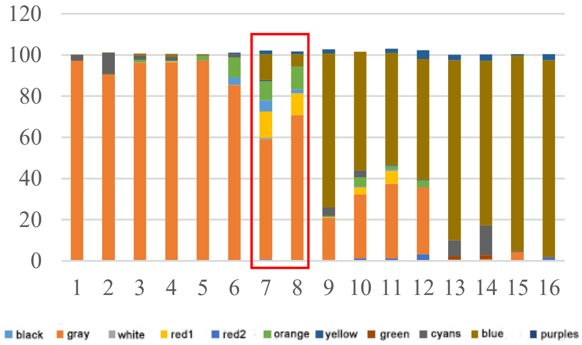

Figure 10. The data of typical color combinations.

5.2 Monochrome

The second color combination, monochrome, accounted for 33.82% of the entire sample. This particular type predominantly employs black, white, and gray as the primary colors, which dominate a significant portion of the concept art. Subsequently, a singular color is utilized to accentuate the visual center. Figure 11 illustrates the distribution of colors, indicating that black accounted for 55.50%, while white accounted for 18.17%.

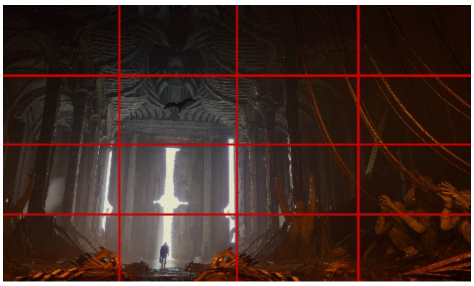

Figure 11. The data of monochrome color combination [19].

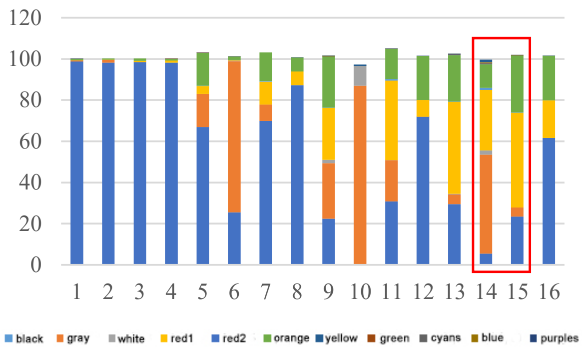

Figure 12. The data of monochrome color combination.

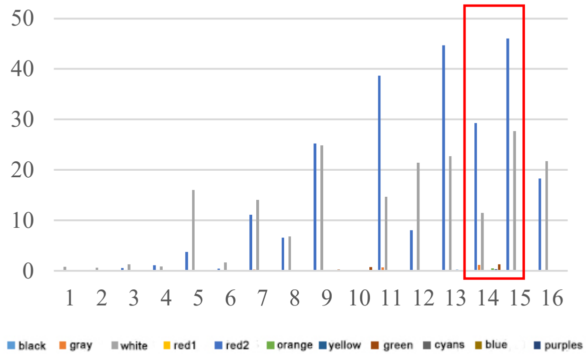

Figure 13. The data of monochrome color combination.

Consequently, black and white colors collectively constitute most of the game's concept art. Because of the large proportion of black and white, we created additional tables for this type of sample for color analysis. After removing the proportion of black and white colors, we generated Figure 13. Overall, red comprises 14.61% of the entire composition. However, when narrowing our focus to the visual center, the proportion of red significantly escalates to 49.39%. In this specific method of color combination, the singular color used can be any hue, yet it predominantly appears exclusively within the visual center, assuming a considerably higher proportion in the visual center.

5.3 Balance

The final color combination, referred to as "balanced," accounted for 29.75% of the analyzed sample. This particular combination did not exhibit strong discernibility of the central visual area within our previous investigation. Thereby there is no red line to highlight the visual center area. As shown in Figure 14, this type of game concept art, they are predominantly based on specific objects to create a visual center such as characters or monsters. In the case of this color combination, the concept art displays a relatively equitable distribution of colors. For instance, as depicted in Figure 15, blue comprises 27.16% of the composition, red accounts for 23.78%, and orange represents 27.29%. This balanced color combination is characterized by a near parity in color proportions.

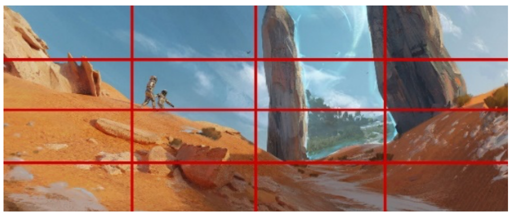

Figure 14. The data of balanced color combination [20].

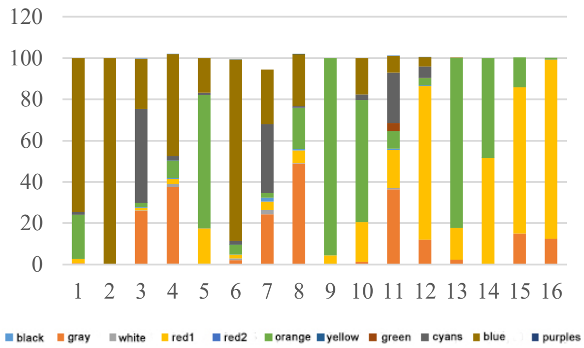

Figure 15. The data of balanced color combination.

5.4 Correlation

Figure 16. One of the experiment examples.

We use an experiment to calculate the positive correlation between color changes and visual center. Fifty participants were recruited for the purpose of discerning the visual center in each image. To facilitate this task, an interactive application was developed by us using Python. Participants were able to designate the visual center of each image through a manual clicking screen. Subsequently, we merge all the results together. As shown in Figure 16, the regions where the dots exhibit the greatest density serve as the visual center. and we compared these results with the conclusions in this paper and judged them true if they matched, or false if they did not match. In the end, the number of samples judged true in all samples of typical and monochrome reached 85.71% of all samples.

6. Conclusion and future work

In the culmination of this investigation, we have meticulously examined 1600 local regions within the game concept art, resulting in the identification of three primary color combinations. Furthermore, we have successfully discerned and characterized the attributes of these combinations, encompassing proportion, saturation, lightness, and hue. Additionally, we have empirically verified the association between color contrast and the visual center, establishing a positive correlation wherein heightened color contrast corresponds to the visual center.

Subsequent to the aforementioned conclusions, we acknowledge several limitations in this study. The analysis of colorful, cartoon-style samples poses challenges in drawing relatively accurate inferences due to their inherent complexity and vividness. Additionally, it is plausible that inadvertent segmentation of crucial areas during the image segmentation process may lead to inaccuracies in the analysis results.

Moving forward, we intend to pursue more extensive research in two key areas. Firstly, we aim to optimize the outcomes of our current experiments. Given the absence of a definitive standard in painting or art, we endeavor to refine the range of color values, thereby enhancing the practical applicability of our findings within the realms of painting instruction and AI-based painting systems. Secondly, our focus will shift towards investigating additional factors that influence viewers' attention in the context of digital artwork. For instance, we shall explore the impact of specific objects or diverse compositional arrangements in directing viewers' gaze toward the visual center.

Reference

[1] A. Jahanian, S. Keshvari, S. Vishwanathan, et al. Colors–Messengers of Concepts: Visual Design Mining for Learning Color Semantics[J]. ACM Transactions on Computer-Human Interaction (TOCHI), 24(1): pp.1-39, 2017.

[2] H. Yamazaki, K. Kondo. A method of changing a color scheme with Kansei scales[J]. Journal for Geometry and Graphics, 3(1): pp.77-84, 1999.

[3] G. Hu, Z. Pan, M. Zhang, et al. An interactive method for generating harmonious color schemes[J]. Color Research Application, 39(1): pp.70-78, 2014.

[4] X. Chaochu. The Current Issue of the Digital Game Concept Art Education for Chinese Undergraduates[J]. International Journal of Information and Education Technology, 9(6): pp.419-422, 2019.

[5] D. DeCarlo, A. Santella. Stylization and abstraction of photographs[J]. ACM transactions on graphics (TOG), 21(3): pp. 769-776, 2002.

[6] Chang H, Fried O, Liu Y, et al. Palette-based photo recoloring[J]. ACM Trans. Graph., 2015, 34(4): 139:1-139:11.

[7] Pavan Kumar I, Hara Gopal V P, Ramasubbareddy S, et al. Dominant color palette extraction by K-means clustering algorithm and reconstruction of image[C]//Data Engineering and Communication Technology: Proceedings of 3rd ICDECT-2K19. Springer Singapore, 2020: 921-929.

[8]C. Nodine, C. Mello-Thoms, E. Krupinski, et al. Visual interest in pictorial art during an aesthetic experience[J]. Spatial vision, 21(1-2): pp.55-77, 2008.

[9] C. G. García, F. García-Sánchez, J. S.González, et al. Digital Tools for the Didactics of Colour in Fine Arts Studies: Remarks on Colour[C], the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality. pp.742-746, 2018.

[10] Stepanova E. The impact of color palettes on the prices of paintings[J]. Empirical Economics, 2019, 56: 755-773.

[11] C. Zhang, K. Lei, J. Jia , et al. AI Painting: an aesthetic painting generation system[C], the 26th ACM international conference on Multimedia. pp.1231-1233, 2018.

[12] T. San, Y. Kanematsu, K. Mikami, An analysis of visual interest detection in 2D game concept art. Asian Forum on Graphic Science, 33, 2021.

[13] Y. Wang, R. Huang, S. Song, et al. Not all images are worth 16x16 words: Dynamic transformers for efficient image recognition[J]. Advances in Neural Information Processing Systems, 34: 11960-11973, 2021

[14] M. W. Schwarz, W. B. Cowan, J. C. Beatty. An experimental comparison of RGB, YIQ, LAB, HSV, and opponent color models[J]. Acm Transactions on Graphics (tog), 6(2):pp. 123-158, 1987.

[15] M. Zhang, G. Qiu, N. Alechina, and S. Atkinson: A Comparison of Five HSV Color Selection Interfaces for Mobile Painting Search. In Human-Computer Interaction– INTERACT 2015: 15th IFIP TC 13 International Conference, Bamberg, Germany, September 14-18, 2015, Proceedings, Part II 15, 265–273. Springer, 2015

[16] J. Cui: Image Style Migration Algorithm based on HSV Color Model. In 2022 IEEE International Conference on Advances in Electrical Engineering and Computer Applications (AEECA), 111–114. IEEE, 2022.

[17] Artstation - explore. (n.d.). Retrieved September 13, from https://www.artstation.com/, 2023.

[18] Nag, A. Sketches & Studies. Artstation. Retrieved from

https://www.artstation.com/artwork/3da40E.
[19] Tamnev, P. The Heretic. Artstation. Retrieved from https://www.artstation.com/artwork/4bAzE2.
[20] Liang, M. Daily Sketch. Artstation. Retrieved from https://www.artstation.com/artwork/w6mAvV.

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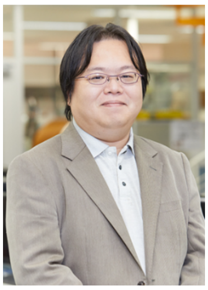

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