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# Investigation of Design Principle for Game Concept Art Through Visual Center Detection and Color Combination

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To my esteemed professors, thank you for your guidance, knowledge, and unwavering support throughout these years of academic pursuit. Your mentorship has not only shaped my academic growth but also nurtured my intellectual curiosity. Your constant encouragement and constructive feedback have challenged me to reach new heights and exceed my own expectations. I am deeply grateful for the opportunities you have provided me and the knowledge you have imparted upon me.

To my family, my rock and my biggest supporters, thank you for always standing by my side. Your unwavering belief in me, your love, and your sacrifices have been the driving force behind my achievements. Your unwavering support has given me strength during the challenging times and has fueled my determination to overcome obstacles. I cannot express enough gratitude for your patience, understanding, and endless encouragement. You have been my pillar of strength, and I owe my success to your unwavering love and support.

To my friends, thank you for being there through thick and thin. Friendship has been a constant source of inspiration, motivation, and solace. Whether it was late-night study sessions, brainstorming ideas, or simply lending an empathetic ear, your unwavering support has made this journey all the more memorable and enjoyable.

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# Chapter 1

# Introduction

The field of design has a longstanding appreciation for the pivotal role that color plays, and within its realm, the study of color combinations has given rise to plenty of diverse research methodologies. These research into color combination has developed a multitude of techniques, each designed to discern and facilitate the harmonious combination of colors with effectiveness. These theoretical frameworks have consistently demonstrated their utility in elevating the execution of design concepts spanning various domains. Furthermore, delving into the realm of color exploration holds promise as a valuable instrument for evaluating the aesthetic value of artistic creations[7]. Thus, this research seeks to introduce an innovative approach to color analysis within the specific context of game concept art.

Prior research on color combinations has often relied on color rings, which offer a limited harmonious color palette. Although these methods have been extensively examined, they cannot be readily applied to the specific requirements of game concept art. The design process for game concept art shares some similarities with visual design, yet it fundamentally differs due to the the visual center in game concept art. Consequently, this study undertakes a systematic differentiation between the visual center and non-visual center regions, conducting a detailed color analysis of each local region. Furthermore, in contrast to conventional color analysis methodologies, the author introduces an additional attribute: the color proportion, to complement the hue, saturation, and value (HSV) attributes. Recognizing that the proportion of different colors profoundly impacts the visual effect of the artwork, the author aims to replicate the creative process of an artist engaged in designing game concept art. The primary objectives involve detecting visual centers and analyzing color combinations in game concept art.

## 1.1 Game concept art

This study's primary goal is to provide a comprehensive examination of the importance of both the visual center and the color proportion in game concept art. By doing so, the author seeks to bridge a noticeable gap in the existing research and emphasize the invaluable insights it can offer to the field of game design. Previous research has covered a diverse array of related investigations, including saliency, object recognition, methods for generating color combinations, assessing color combinations, and analyzing traditional painting color combinations. While these investigations hold relevance in related domains, their direct applicability to game concept design drawings is limited due to several crucial factors.

Foremost, the concept of the visual center in game concept design diverges from the conventional recognition of individual key objects. In this design process, emphasis is placed on an area rather than a singular object. Consequently, research about the recognition of isolated objects cannot yield optimal outcomes when applied to game concept art.

Secondly, the scope of previous research has encompassed diverse design industries, including photography, traditional art, graphic design, and film. While these themes have enriched the understanding of color combination in various contexts, they differ significantly from the distinctive requirements of game concept art. Consequently, the conclusions drawn from these diverse studies cannot be directly transposed to the industrial of game concept art.

Thirdly, the oversight in numerous color-related studies pertains to the neglect of the perceptual impact triggered by color variations. Prior investigations have typically employed different color spaces, such as lab color space, RGB, and HSV, which are indeed relevant for studies on color perception. However, within the realm of game concept art, color changes show more abundantly and diversely. The visual compositions of game concept art often feature complex and multifaceted colors, exceeding the typical range observed in photographs or films. In light of this intricacy, the ratio of colors becomes an indispensable research factor that cannot be disregarded. Regrettably, many prior studies have not adequately addressed the pivotal role of color proportion in influencing visual perceptions.

## 1.2 Purpose and target

The original intention of the author's research was to create the author's own research methodology through an artist's perspective. The methodology was used to analyze more systematically the color combinations in the game concept art.

The target users of the application are game concept designers. the author hopes the author's specialized way of categorizing visual and non-visual center colors will better assist game concept designers. This approach will help them to be more effective in the early draft stage. It will allow them to choose the color combinations for the visual and non-visual areas more easily.

In essence, the author's research endeavors to fill this space by focusing on the unique requirements of game concept art, shedding light on the specific role of the visual center and the intricacies of color scaling within this context. Through this comprehensive approach, the author aims to provide game designers and artists with a more tailored and practical understanding of how these elements influence the overall visual impact of their creations.

## 1.3 Commercial game and independent game

Figure 1.1: Commercial game concept art

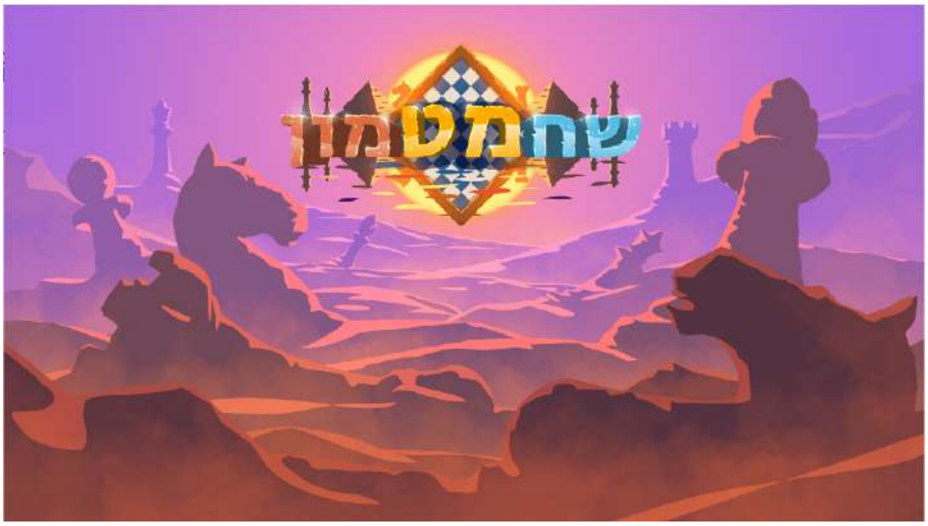


Figure 1.2: Independent game concept art

The author has listed a commercial game in Figure 1.1 and an independent game in Figure 1.2 in the picture. Commercial games and independent games play different roles in the game industry. Commercial games are supported and developed by large development teams or publishers with large budgets and resources. These games usually aim for high-quality visual effects, sound effects, and broad entertainment value to attract more players. They usually need to take into account market demand and popular tastes and gain a competitive edge in the market through large-scale marketing and promotional campaigns. As a result, commercial games tend to have a longer production process and need to meet the challenges of commercialization and market competition.

In contrast, independent games are produced by small teams or individual developers and are usually more limited in budget and scale. These games focus on originality, innovation, and uniqueness, and developers have more freedom to realize their creativity and ideas. Indie games have shorter development cycles and focus more on the innovation and unique experience of the game itself. Although marketing budgets are limited, indie games can gain a certain degree of attention by promoting their games through channels such as word-of-mouth, social media, and game shows.

Commercial and indie games also differ in game genres and market positioning. Commercial games usually cover a wide range of genres, from massively multiplayer online games to action-adventure, shooting, and role-playing games, aiming to satisfy the needs of different types of players. Indie games, on the other hand, are usually more focused on a specific genre or a specific experience and may choose to explore new gameplay, emotional experiences, or artistic styles.

In summary, commercial games and indie games differ significantly in terms of development scale, capital investment, creative pursuits, and market positioning, but they each play an important role in the gaming industry, meeting the needs and expectations of different types of players. Therefore, commercial games have a much larger capital investment in art. This also means that they have higher demands on the quality of their art concepts. Their requirements on the technical aspects of art are more perfect. Therefore, the author has chosen commercial game concept art as the target of the author's research.

## 1.4 Research frame work

To investigate the principles of color combinations in game concept art, this research is separated into two main components: the detection of visual centers within game concept art and the color combination rules about both visual and non-visual centers.

Before initiating the experimental phase, meticulous sample preparation was conducted. A total of 100 samples were gathered from the prominent game concept art community "artstation"[9] renowned for showcasing exemplary game concept art worldwide. These samples were randomly selected to encompass a diverse array of scene concept design drawings, showcasing distinct game genres and varied painting styles. The author chooses commercial game concept art as the author's samples.

Subsequently, the investigation delved into detecting the visual center, a process that entailed three major steps: image segmentation, application of the perceptual hash algorithm, and identification of visual interest.

During image segmentation, existing research was consulted, leading to the adoption of a 4*4 local region segmentation approach. For each local region, a corresponding hash string was generated to represent its color variation. Subsequently, similar local regions were grouped, and those with fewer resemblances were identified as visual center areas. A comprehensive evaluation was then conducted, and the visual center areas were confirmed through a survey. Notably, the accuracy of the author's results exceeded those obtained via other saliency methods.

The second component involved the segregation of visual center and non-visual center local regions, followed by a comprehensive analysis and synthesis of color combinations. Based on the conclusions derived from the earlier research, the local regions were categorized accordingly. The HSV (Hue, Saturation, Value) color space was chosen for color analysis, owing to its suitability for human color perception and cognition. Color intervals were defined within the HSV space, and subsequent investigations delved into the color combinations for each local region within the respective intervals. Three distinct color combinations were analyzed and summarized: typical, balanced, and monochrome. Furthermore, the proportions of individual colors within each combination were extracted and examined.

Ultimately, both lines of inquiry were amalgamated, culminating in a comprehensive conclusion and discussion, which serve as the denouement of this thesis.

As shown in Figure 1.3, The research framework about the Vision Center comprises the following components:

- Sample Selection and Sample Cutting: The initial phase involves the careful curation of samples and the precise segment of each image.
- Embedding Hash String for Each Picture: Hash strings are applied to individual local regions, serving as concise representations of their respective color variations.
- Classification of Similar Local Regions: An organized classification is conducted for local regions within the images, facilitating the identification of areas exhibiting low similarity, subsequently designated as the visual center.
- Verification of Visual Center Correctness: The HSV change value of color is used as a criterion to evaluate and ascertain the accuracy of the designated visual center.
- Experimental Validation of Visual Center Correctness: Rigorous experiments are conducted to evaluate the accuracy of the identified visual center.

The primary body of this scholarly paper is partitioned into two core segments: the investigation of the visual center and the formulation of color combination principles within the game concept design diagram. In Section 3, the author presents a comprehensive exposition of the distinctive attributes of the author's selected samples. As illustrated in the figure, both relevant research and methodologies will be expounded upon, each within its respective domain.

Chapter 3 also focuses on the scrutiny of vision center detection and encompasses an introduction, related research, research methodologies, evaluation, conclusion, and discussion. Pertinent research within this chapter encompasses saliency, object recognition, visual interest in traditional art, and composition. Methodological aspects encompass a detailed delineation of three procedural steps.

Chapter 4 is dedicated to the analysis of color combinations, and it encompasses an introduction, related studies, research methodologies, conclusions, and discussions. The methodological framework within this chapter entails the demarcation of the visual center, delineation of the HSV color interval, and comprehensive data analysis.

Finally, the author makes a general discussion and conclusion in chapters 5 and 6.

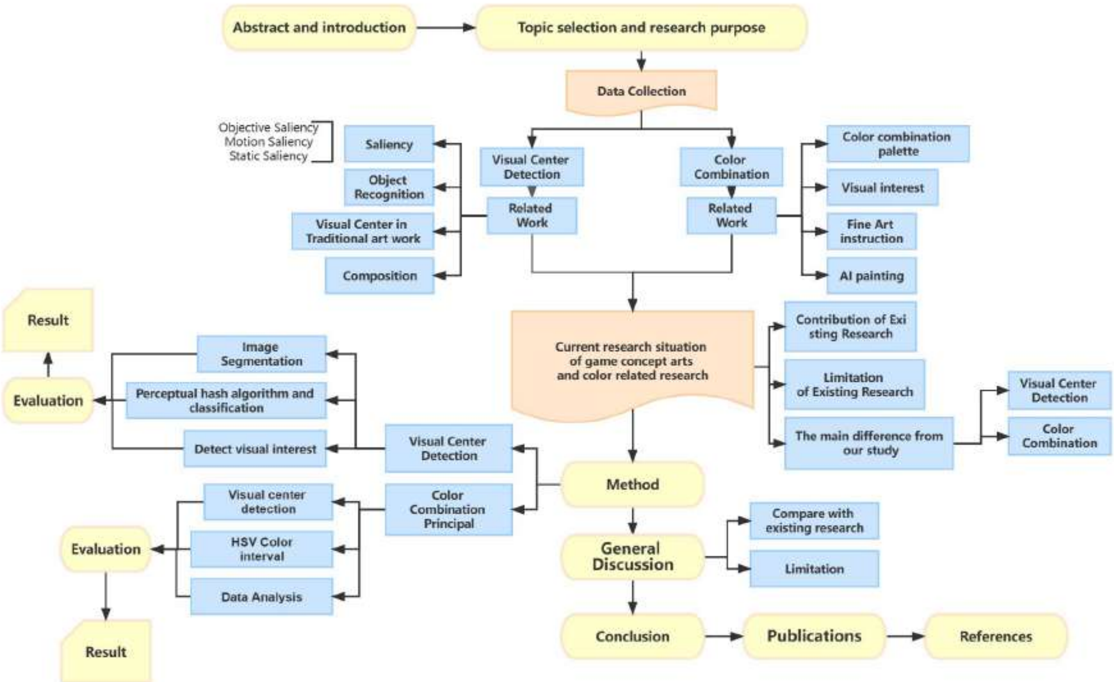


Figure 1.3: Research Map of entire paper

# Chapter 2

# Related Work

There are many related or similar studies in recent research, including Saliency, image recognition, the study of the visual center in traditional artworks, composition, and aesthetics. The following will briefly overview these researches and describe the relationship and differences between their studies and my study.

## 2.1 Saliency

Saliency is an analysis of virtual objects in a series of pictures. In earlier studies, Saliency was based on pixel information to make objects stand out from their surroundings and thus get peoples' attention [13]. It uses image processing technology and computer vision algorithms to locate the most significant area in the picture. The salient area refers to the eye-catching area or the more important area in the picture. The objects of this type of research are mainly photos. Saliency's research has many different methods and is constantly optimizing.

There are three main saliency detection algorithms in the saliency module of OpenCV:

Static saliency: this algorithm relies on image features and statistical information to locate the saliency area in the image.

Motion saliency: The target of this saliency method is videos or a series of frames. This algorithm tries to detect and track mainly moving objects as the saliency areas.

Objectness saliency: This type of saliency algorithm calculates proposal areas; these are considered saliency areas.

Recent research on saliency has focused on some detail factors, such as the relationship between compositional balance and saliency [14], the research using color and depth attention rules to improve the saliency algorithm from D-RGB image [15], and re-design the programming framework to improve the accuracy of saliency [16].

The main difference between saliency's research and my research is the target samples. In saliency research, authors are looking for a way to detect the particle objects in the photos. It depends on the analysis of edge detection, pixel information, and other methods to confirm the weight function of the object in the photo. Especially in the most extensive dataset MSRA, most samples have a clear main object in the pictures. However, the game concept artwork is almost large scenes, and usually, there is no single object in the picture. Game concept art usually connects all the objects in the painting. This work is made with the assumption that concept artists are focusing on an attention area rather than frameable objects. It refers to an area in which there can be one or more objects. The concept art design is a subjective creating process, but it also follows certain objective principles during the design process.

## 2.2 Object recognition

Object recognition is part of the vital references for my research. There are some research on object recognition in images. Previous research [17] proposed that 16*16 would be the best segmentation for object recognition in images or photos. However, it was mentioned in the work of Wang [18] that the picture segmentation should depend on the target object. As shown in Figure 2.1, cutting with a smaller level will save the calculation cost and achieve similar results when the image is elementary, such as apples and oranges. A 4*4 subdivision is sufficient for larger objects to identify the object's content in the picture.

Based on these studies, my research will adopt a 4*4 level segmentation to subdivide and analyze the image. In the future, I do has plans to continue to enrich the research on the results of different level segments.

## 2.3 Visual center in traditional artwork

This study analyzed what factors specifically guide the viewer's gaze in traditional paintings by tracking the participants' gaze. Participants were asked to write down feedback after viewing the digital versions of eight artworks [1]. One example is in Figure 2.2.

The research attempts to analyze the way that audiences obtain information. They get the result by using the processing model and visual aesthetics principle. According to this model, the perceptual-cognitive processing of artistic stimuli starts

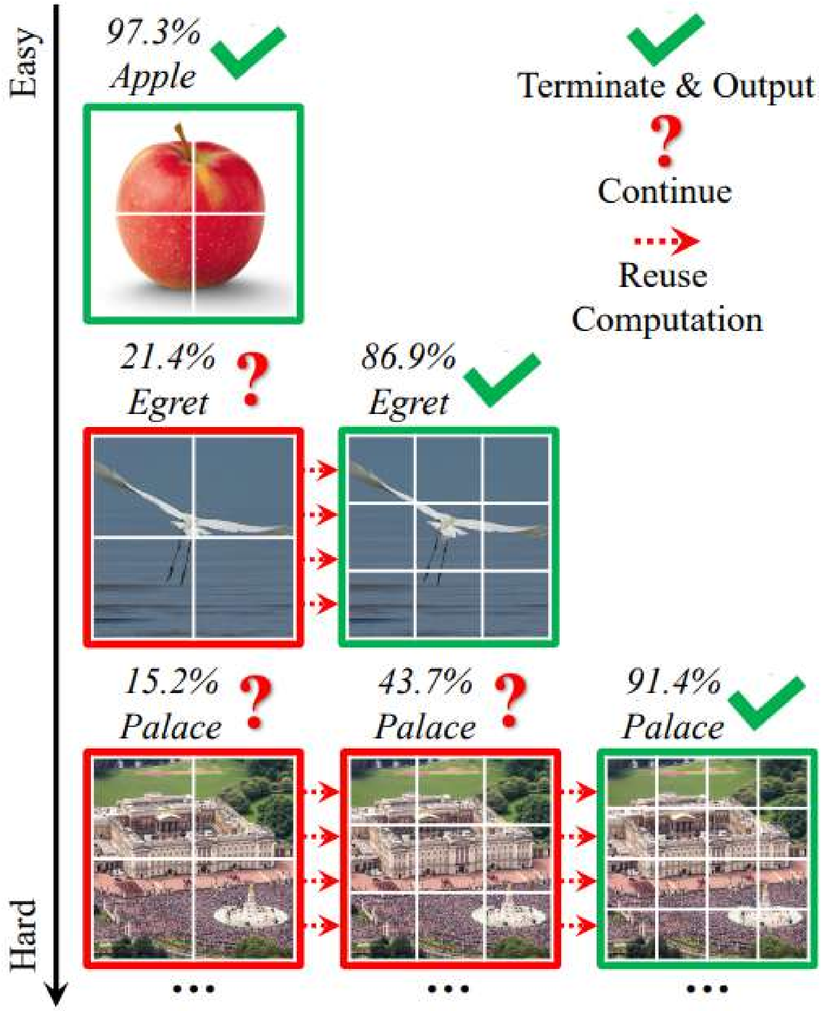


Figure 2.1: 4*4 segmentation is good enough to recognize the content in the image. [1]

with the rapid generation of essential responses, and researchers are looking for the connection between aesthetic methods and audience responses. This research is more closely related to my research than saliency. To a certain extent, I am also looking for the connection between design principles and audiences' attention. Nevertheless, my methods and module are based on the artist's way of thinking. Because the painting principles have already set the ways to connect with the audience. One of the critical processes is guiding the audience's attention. So, the final goals of the two studies are quite similar, but the starting points and methods are entirely different.

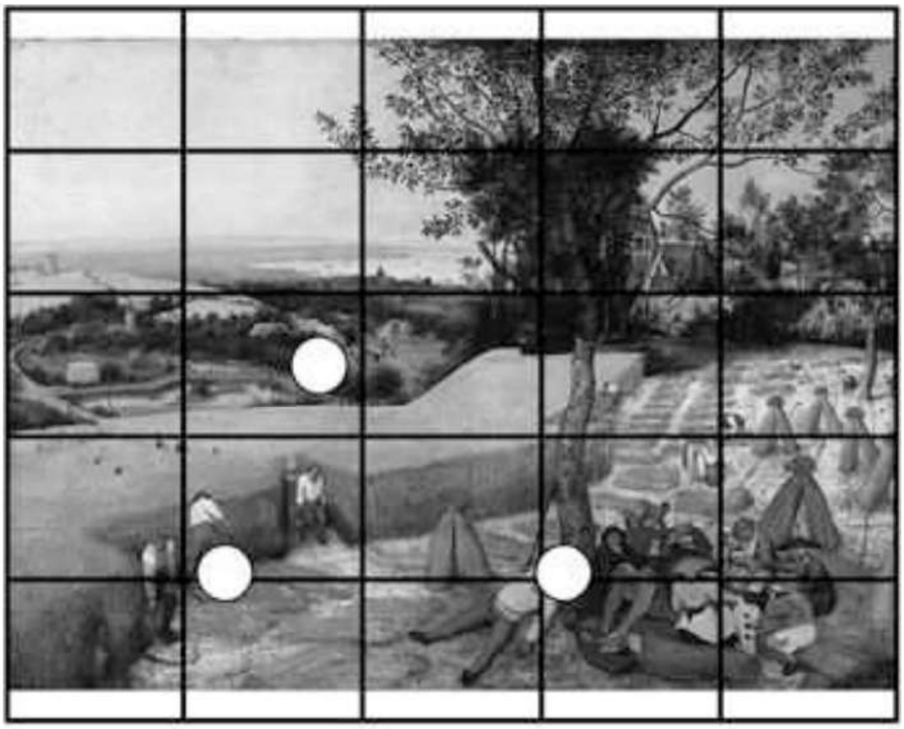

Figure 2.2: An example of visual interest research [1]

## 2.4 Composition

Whether in saliency, the algorithms used do not assume that the images have been created using artistic principles. But some research noticed that. The study of Chen et al. [6] includes the basic composition principle and saliency algorithm. It mentions that composition is one factor that can affect people's attention. The composition has always been an unavoidable problem, such as triangle composition, the golden ratio, and the rule of third. Composition is indeed one of the ways to guide the sight, but artists do not only use composition to guide the audience's sight. In the module of my research, I include the influence of some composition factors. At the same time, I combined the other art principles to improve the accuracy and reliability of my result.

## 2.5 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.


Figure 2.3: In this study, they linked the color combinations of magazine covers to magazine themes. The link between the color combinations and the content of the magazine was proved to exist.[2]

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 2.3[2]. 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.

This research is similar to my investigation; however, it focuses on a different domain. My 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

[19], wherein strokes and area segmentation were performed based on photo colors, subsequently exploring the impact of objects on saliency. However, my study differs from theirs in two primary aspects. Firstly, my focus centers on game concept artwork, which possesses a comprehensive and more exaggerated color and shape. Secondly, my investigation emphasizes the analysis of color combinations, with a specific focus on discerning the disparities between the visual and non-visual centers.

## 2.6 Fine art instruction

The next example applies the findings to the realm of fine art instruction [20]. 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 my comprehension of color. This advancement enables the formless attribute of color to possess value and enables a more objective analysis.

## 2.7 AI painting

In recent times, there has been a surge in the development of AI painting systems, exemplified by the disco diffusion approach [21]. 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 room for improvement in color and composition as well. The objective of my research is to contribute to the enhancement of such AI systems by providing more precise parameters for color combinations. Specifically, this entails incorporating selection intervals for hue, saturation, and lightness, along with considerations for the proportion of each single color.

## 2.8 Differences with existing research

Game concept art is a very important aspect of game development that involves creativity, art, and visual presentation that lays the foundation for the look and feel of the game. These design pieces can include, but are not limited to: designing the game's characters, including protagonists, enemies, NPCs, terrain, buildings, vegetation, weather effects, etc., and seek to create a unique visual style for the game. These designs need to be clean and intuitive while matching the overall style of the game. Draw conceptual artwork showing in-game scenes, characters, props, etc. to provide a visual understanding to the development team and decision-makers.

These design works are usually presented in the form of sketches, paintings, digital drawings, or 3D modeling. Concept design artists need to have solid artistic skills, creativity, and an understanding of game world-building in order to translate game concepts into visually pleasing presentations. These game concept art pieces not only guide game development but also help teams and stakeholders better understand the overall visual style and direction of the game. Environment design is an integral and critical part of game development. It is responsible for creating the various scenes, terrains, and backgrounds in a game to provide players with an immersive experience. Designers use drawing software, 3D modeling tools, and game engines to create engaging, attractive, and iconic game environments that take into account the story of the game, the player's experience, and technical constraints. They create specific atmospheres through colors, materials, music, and other elements to add realism and emotion to the game, thus enhancing the player's perception and interaction.

Game concept art drawings are significantly different from ordinary photos, and movies. First of all, they are embodied in creativity, Game concept art is created for fictional worlds or scenarios, and is mainly used to display concepts such as characters, scenes, props, and so on in the game. Concept art drawings are highly creative and artistic, often presenting fantasy, science fiction, or unique visual styles to trigger the viewer's imagination and curiosity. In contrast, ordinary photographs and movies usually capture real scenes or people in the real world, focusing on recording or presenting real-life scenes, people, and events. The second difference is their form and use. Game concept art is primarily used in the early stages of game development. It is an image created by designers and development teams to express game concepts and ideas. These images can be sketches, concept art, or digital drawings that show the setting of the game world, character modeling, scene placement, etc. and are used to guide subsequent game development efforts. These artworks are usually designed to express concepts and show elements of fictional worlds that, while visually appealing, lack actual interactivity and serve only as a starting point for game creation. Common photographs and movies, however, are primarily used to document real-life scenarios or tell a story for the viewer's enjoyment or to gain information. Photographs and movies are based on real visual presentation and are used to show scenes and plots in the real world. Photographs and movies present real scenes and stories, and viewers can directly experience, feel, and understand what is shown in them by watching the photographs or movies.

Generally speaking, game concept artwork is the product of the initial stage of game development, focusing on the creation and expression of the fictional world, while ordinary photos and movies focus more on the recording and presentation of the real world. There is a clear difference between the two in terms of creation purpose, display form, and viewing experience.

# Chapter 3

# Visual Center Detection

## 3.1 Introduction

In the introduction section, it is mentioned that I divided the whole study into two parts to complete my color analysis of the game concept arts. The first part is the point of difference that distinguishes it from most of the studies that have been done, namely the visual center. In previous studies, the analysis of images is mostly based on the analysis of the whole picture. As well as analysis for specific objects in the image, such as edge detection, object detection, saliency, etc. The main difference between game concept art and photographs and images is that game concept art is the product of an artist's design. The design process involves many different factors, such as color, composition, rhythm, visual center, and so on. The visual center has been neglected in previous studies of images.

To better illustrate the idea of the visual center, I use two diagrams to show the importance of the visual center in game concept art and how designers use the visual center to guide the viewer's eyes.

As shown in Figure 3.1, the light and shadows in the whole picture are determined by the designer. Therefore the designer has first guided the viewers through the contrast of lightness. Secondly, the sight of the two characters in the picture also acts to direct the area in the center of vision. Finally, there is the obvious contrast between complexity and simplicity: the area in the center of the visual area is the one that the artist spends more time shaping, and is richer and more informative than the two sides of the frame. The above-mentioned design methods will be taken into account from the point of view of the average viewer, but their eyes will be guided coincidentally to the same area, which is shown in Figure 3.2.

From this, it is pretty clear that the difference between comparing the visual center and other picture-related studies. The visual center refers to a relatively vague range

Figure 3.1: An example of game concept art.

rather than an exact object. Therefore many previous studies do not identify the area of the visual center very well. This is the main reason why I am taking this part in my research. The second is that, unlike photographic art, designers of game concept art receive fewer limitations, and they can freely control the placement of light and shadow objects. my sample for this study is also based on game concept art. Game concept art has more room for designers to maneuver. The art of photography is often limited by the conditions of the real world, including the placement of objects, the rendering of colors, and so on. This study seeks to fill the gap between previous studies that focus on individual objects or edge detection, and those that address game concept design in digital media art.

My main goal in this phase was to accomplish the detection of the visual center in the game concept art. To achieve this goal, I tried to complete the algorithm from a designer's point of view. In the end, I passed a test to determine if the results were accurate and outperformed other similar algorithms.

After the author successfully determined the visual centers of 100 sample images using the novel algorithm I devised. Given the inherently subjective factor of the visual center concept, the author seek to validate my conclusions through an experiment designed to identify the visual center of these sample images from the viewer's perspective.

This section commences by introducing two saliency methods employed for comparative analysis: object saliency and static saliency. While object saliency primarily focuses on object recognition, static saliency delves into pixel-level variations. Within

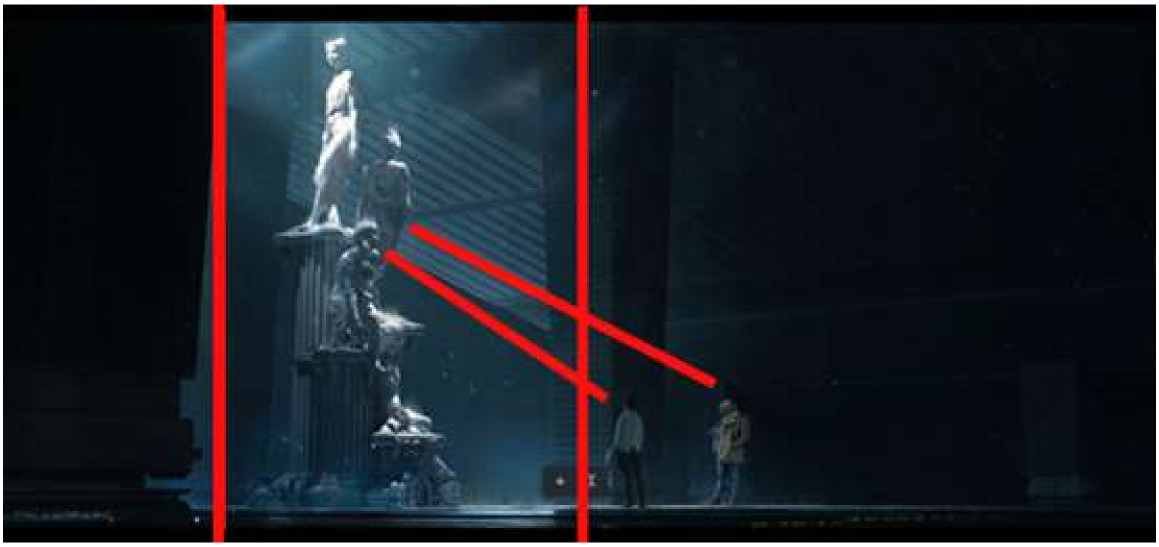

Figure 3.2: The red area in the middle of the diagram contains very rich content to attract the viewer's attention. Secondly, the two characters in the figure also direct the center of vision by their orientation and line of sight.

the related work section, the author provide a detailed exposition of their respective methodologies for detection, accompanied by insights into related research and practical applications. Additionally, I reference studies that incorporate tracking mechanisms, highlighting distinctions between my study and theirs. Notably, their research primarily targets eye detection, though it still exhibits certain limitations related to tracking accuracy.

Subsequently, the author elucidates the approach to conducting the experimental test. Initially, the author assembled a group of volunteers in a library setting to participate in the experiment. the author commenced by imparting a clear understanding of the concept of the visual center to the participants. Participants then utilized a program to identify and mark the areas they perceived as the visual center within the images. At the culmination of the experiment, the author amalgamated all participants' clicking results into one single picture, ultimately determining the visual center area.

Conclusively, the author undertook a comparative analysis, comparing the outcomes of this experiment with those generated by my algorithm and the results generated by the two saliency algorithms. The discernible trend that emerged from this comparison was the superior accuracy of my algorithm in identifying the visual center, as opposed to the saliency methods.

The end of this section encapsulates the conclusions drawn from the experiment, elucidating the discoveries made. Simultaneously, the author acknowledges and addresses the encountered problems and limitations that warrant further consideration and exploration.

## 3.2 Related Work

In the related study, the author will encapsulate four parts of the study. the author will roughly divide them into four parts Saliency, object recognition, visual center in traditional artwork, and composition. All these studies are similar to my first topic. the author will explain them in detail below, comparing the similarities and differences of my studies.

### 3.2.1 Saliency Dataset

The first study the author has to mention is saliency. Saliency is the analysis of virtual objects in a series of pictures. In early research, saliency was based on pixel information to make objects stand out from their surroundings and thus attract our attention [13]. Saliency is often used in various fields such as psychology, neuroscience, computer vision, and design to describe how something or aspect stands out from its surroundings and attracts our attention.

Saliency research, in the context of computer vision and cognitive psychology, is a multidisciplinary field that investigates how humans and computer systems allocate attention and prioritize certain regions or objects within visual scenes. It primarily focuses on identifying visually salient regions within images or videos—areas that stand out or capture human attention more readily.

Saliency in the context of images refers to the relative importance or prominence of an object, area, or feature in an image or scene. When I view an image, our eyes are naturally drawn to the most prominent or visually salient areas. Prominence is affected by a variety of factors, including color, contrast, motion, size, and novelty. Elements that are different from their surroundings in terms of these factors may be more noticeable. saliency is used in areas such as graphic design, advertising, web design, and user interface design to create visually compelling and effective content. It is also used in computer vision and image processing to develop algorithms that can automatically identify and focus on salient regions in images and videos.

Recent research on saliency has focused on detailed factors such as the relationship between compositional balance and saliency [14], research on improving D-RGB image saliency algorithms using color and depth attention rules [15], and redesigning programming frameworks to improve saliency accuracy [16]. The main difference is

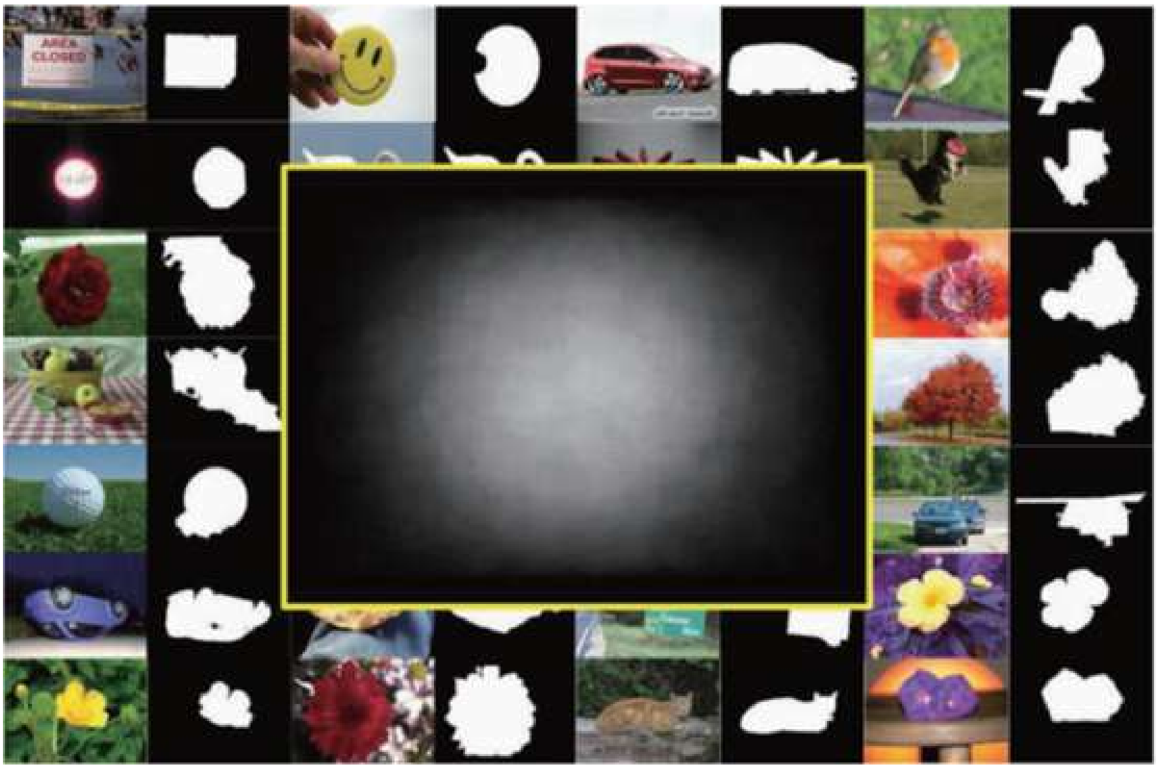

Figure 3.3: MSRA Data set is a database commonly used for saliency research. Most of the samples have one main object occupying the center of the image. There is a big difference between this kind of picture style and the game concept design drawing.

the target sample. In the saliency study, the authors are looking for a way to detect pixels in a photo. Methods such as pixel information are analyzed to confirm.

Weight function of the objects in the photos. As shown in Figure 3.3, in the dataset MSRA, most of the samples have clear main objects in the pictures. However, game concept art is almost always large scenes and usually has no individual objects in the picture. Game concept art usually connects all objects in the painting.

This work is done under the assumption that the concept artist is focusing on regions of interest rather than frameable objects. It refers to areas where one or more objects can exist. Conceptual art design is a subjective creative process, but the design process also follows certain objective principles.

Researchers in this field seek to model and understand the mechanisms underlying visual attention. This involves studying how humans naturally fixate on specific parts of an image or video and what factors contribute to the saliency of those regions.

Saliency research has led to the development of computational algorithms and models that can predict where humans are likely to look in a visual scene. These models use various visual cues, such as color, contrast, texture, motion, and objectness, to estimate saliency maps that highlight salient regions.

Saliency research has numerous practical applications, including image and video compression, content-aware image retargeting, object recognition, autonomous navigation, and advertising. By understanding and modeling visual attention, these applications can be optimized for better user experiences and improved efficiency.

Despite its many contributions, saliency research also has some limitations:

Visual saliency can be highly subjective, varying from person to person and depending on context. What one person finds salient may not be the same for another. This subjectivity makes it challenging to create universal saliency models.

While saliency maps generated by algorithms can predict regions of interest, they do not always correspond perfectly to actual human eye movements. These maps provide estimations but may not capture the intricacies of human visual attention.

Saliency is often context-dependent. What is salient in one context may not be in another. Algorithms may struggle to adapt to changing contexts and dynamic scenes.

Saliency research faces difficulties in dealing with complex scenes with multiple salient objects or regions. Determining how attention is distributed across these elements can be challenging. At the same time, most saliency research focuses on pictures and videos. There is no corresponding optimization for the game concept design drawings. Therefore they did not present a good result when applied to my study sample.

Cultural and individual differences in visual preferences can further complicate saliency modeling. What is salient may vary across cultures and among different individuals.

Despite these limitations, ongoing research in saliency continues to advance our understanding of how humans perceive and attend to visual information. Addressing these challenges is crucial for improving the accuracy and applicability of saliency models in various computer vision and human-computer interaction applications.

### 3.2.2 Objectness Saliency

Objectness saliency is a computer vision and image processing technique used to identify and highlight objects of interest within an image or scene. Unlike traditional saliency methods that focus on detecting any visually salient regions, objectness saliency specifically aims to locate and emphasize the most probable object-like regions in an image.

As shown in Figure 3.4, the concept behind objectness saliency is to replicate how humans typically perceive and pay attention to objects within a scene [3]. It takes into

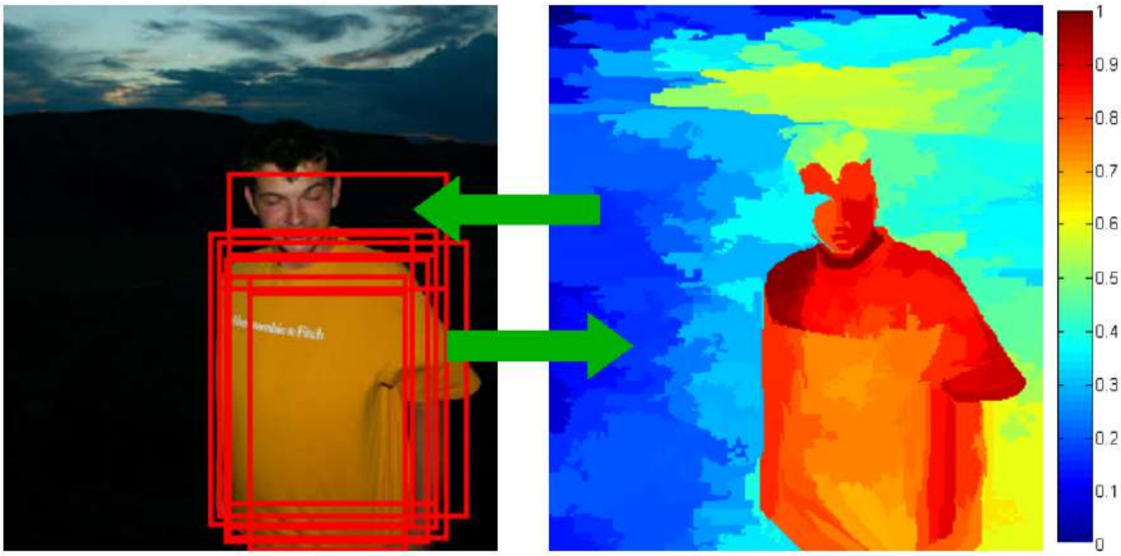


Figure 3.4: An example of objections saliency[3]

account various visual cues and features, such as color, texture, shape, and contrast, to identify regions that are likely to contain meaningful objects or entities. By doing so, objectness saliency helps in automatically drawing attention to potential objects or areas within an image, making it a valuable tool in tasks like object detection, image segmentation, and scene understanding in computer vision applications.

### 3.2.3 Motion Saliency

Motion saliency, in the context of computer vision and visual attention modeling, is a concept that pertains to the detection and identification of visually conspicuous or salient motion patterns within a video or a sequence of images. It is a key component in understanding how humans perceive and attend to moving objects in dynamic scenes.

As shown in Figure 3.5, motion saliency algorithms analyze the temporal changes in an image sequence, focusing on aspects such as speed, direction, and acceleration of objects or regions within the video[4]. These algorithms identify areas or objects that stand out due to their motion characteristics and draw attention to them. This capability is particularly useful in applications such as action recognition, object tracking, video summarization, and autonomous navigation, where recognizing important moving elements is critical.

In essence, motion saliency seeks to replicate the way humans naturally prioritize

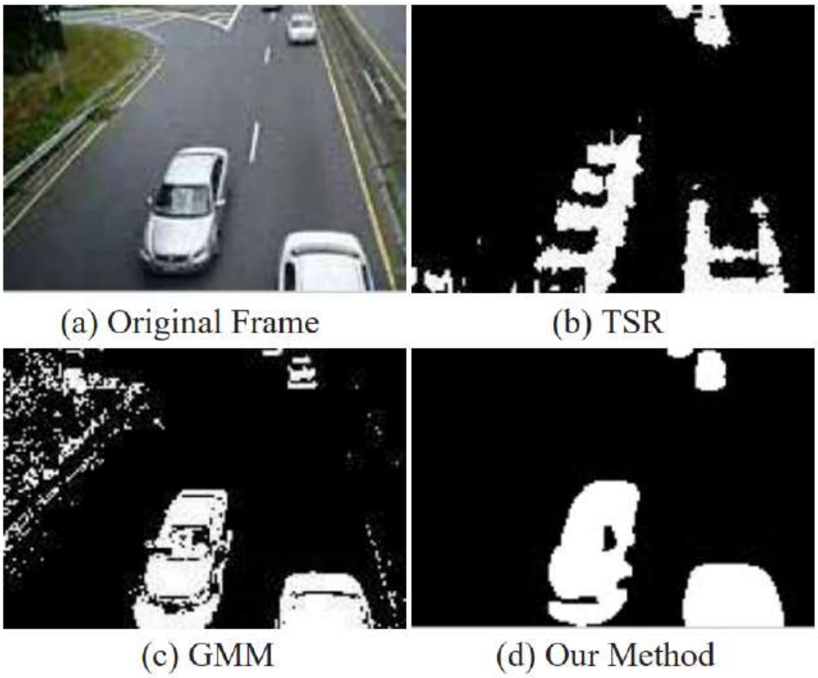


Figure 3.5: An example of motion saliency[4]

and attend to dynamic elements within their visual environment, making it an essential component in various computer vision tasks and technologies, including robotics, surveillance, and video analysis.

### 3.2.4 Static Saliency

Static saliency, in the field of computer vision and visual attention modeling, is a concept that focuses on identifying and highlighting visually significant or salient regions within a single static image. Unlike motion saliency, which deals with dynamic changes over time in videos, static saliency algorithms analyze a single, stationary image to pinpoint areas that are visually conspicuous based on various visual cues.

These visual cues can include factors such as color contrast, texture variations, luminance differences, and the presence of distinctive edges or patterns. Static saliency models aim to replicate how the human visual system naturally prioritizes and directs attention to specific regions or objects within a scene, even in the absence of motion.

Static saliency, As shown in Figure 3.6, plays a fundamental role in various computer vision applications, including image segmentation, object recognition, image compression, content-aware image retargeting, and automated cropping [5]. By iden-


Figure 3.6: An example of static saliency[5]

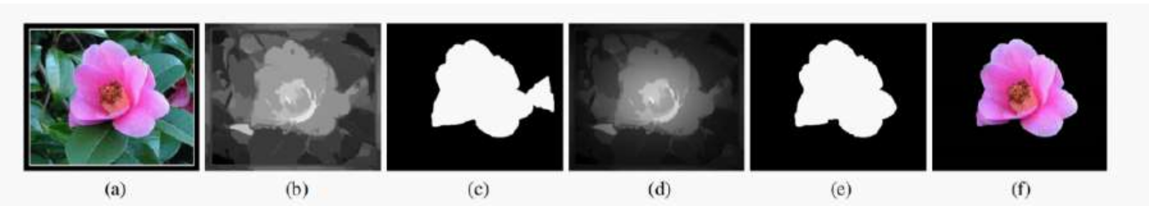


Figure 3.7: The figure shows several saliency methods. It is not difficult to see that most saliency methods focus on the detection of a single object.[6]

tifying and emphasizing the most salient regions, these algorithms improve the efficiency and accuracy of tasks that involve processing and understanding static images, ultimately enhancing human-computer interaction and visual analysis.

### 3.2.5 Main object detector

Object recognition is the ability of a computer or human to recognize and classify objects or entities in the surrounding environment based on their visual or sensory characteristics. The process involves analyzing and interpreting data from images to determine the presence and type of objects in a scene. The process of recognizing and classifying objects or entities in image, video, or sensor data, it plays a vital role in various fields, especially in computer vision, artificial intelligence, and robotics. Advances in deep learning and computer vision techniques have significantly improved the accuracy and applicability of object recognition systems.

In computer vision, the first step in object recognition is often feature extraction. This involves identifying unique features or patterns in the data that can be used to distinguish one object from another. Features can include edges, texture, color, shape, etc. However, object recognition in this type of research faces challenges such as occlusion (partial hiding of objects), changes in scale and viewing angle, changes

Figure 3.8: The example of 2*2 segmentation[6]

in lighting conditions, and the presence of clutter in the environment. For example, as shown in Figure 3.7, in this type of study the sample is a photograph, and because of this limitation, it is difficult to apply it to the game conceptual design drawings[6].

Object recognition is an important part of the reference material for my research. There exist some studies on object recognition in images. A previous study [17] suggested that 16*16 is the best segmentation for object recognition in images or photographs. However, in the study by Wang et al., it was mentioned [18] that image segmentation should be dependent on the target object. When the images are basic (for instance apples and oranges), using smaller levels of cuts will save computational costs and yield similar results. A 4*4 segmentation is sufficient for larger objects to recognize the content of objects in the image. Based on these studies, my research will use 4*4 level segmentation to segment and analyze images. In the future, I do have plans to continue to enrich my research with different levels of segmentation results.

at the beginning of the experiment, as shown in Figure 3.8, I tried low-segmentation like 2*2 segmentation methods. As shown in Figure 3.9, I tried high-segmentation methods like 6*6. 2*2 and 3*3 segmentation would lead to the size of each local region being too large, which makes it difficult to determine the location of the visual center. The 5*5 or more cuts will cut the picture too small, which is not conducive to the comprehensive analysis of the local region in the color combination of the principle. Therefore, I finally chose the 4*4 cutting method.

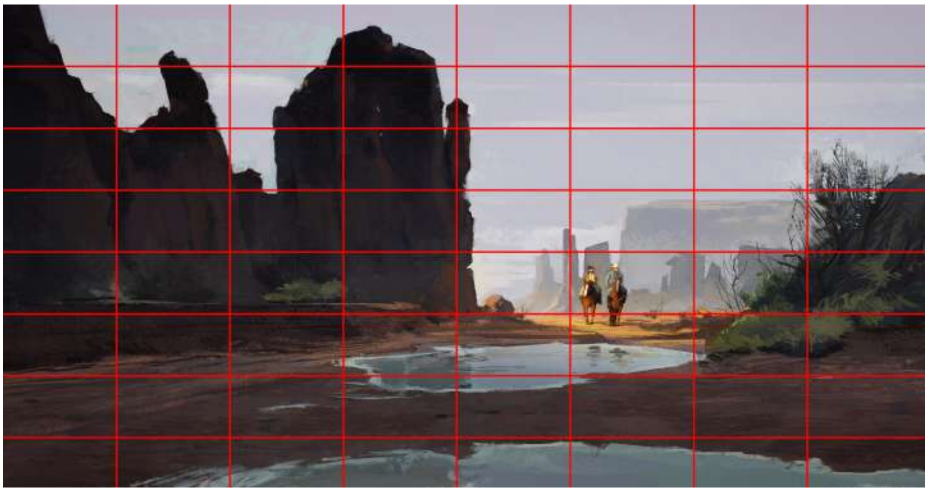

Figure 3.9: The example of 6*6 segementation.[6]

### 3.2.6 Bag of feature model

The Bag of Features (BoF) model is a fundamental concept in computer vision and image processing. It is a technique used for image classification, object recognition, and image retrieval. The BoVW model is inspired by the Bag of Words model in natural language processing.

Originally this type of research was pin computer vision and OBJECT recognition. However, some studies on image analysis have developed their own analysis methods on this basis. For example, in Masashi's research [7], a new analysis method was extended by the BoF model method. As shown in Figure 3.8, they divided the images into very small local regions by cutting the images, and then they regarded the similar local regions as a class. They use this to analyze the distribution characteristics of local regions in excellent photographs. The algorithms eventually led to a system for evaluating photographs. This research inspired us to create a unique algorithm to calculate the visual center of a picture from the artist's approach to creating a picture by using the BoF model method.

### 3.2.7 Other factor influence saliency region

Composition in art refers to the arrangement of visual elements within a work of art. It's a fundamental aspect of creating and appreciating art, as it directly impacts how viewers perceive and interpret an artwork. Composition involves making deliberate choices about how to organize various elements such as lines, shapes, colors, textures, and forms to create a visually pleasing and meaningful whole.

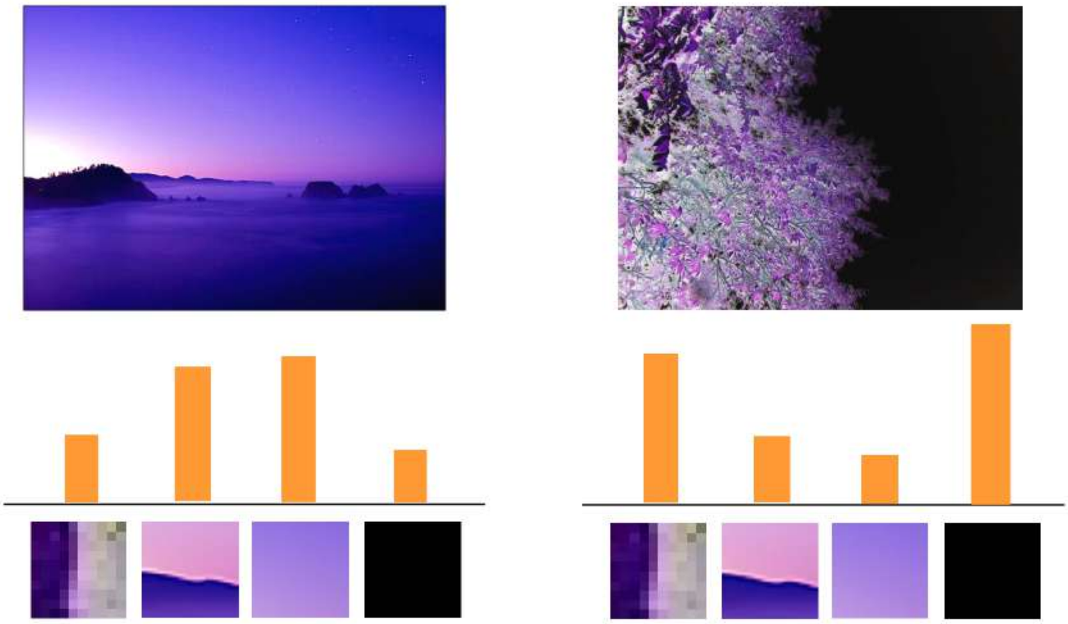

Figure 3.10: Demonstration of the bag of color model, Different from my research, their research is on local regions, while I still analyze pixels in each local region.[7]

In composition, the more commonly mentioned are the rule of thirds, repetition and pattern, golden ratio, and so on. Composition is a highly subjective and creative aspect of art, and different artists may use these principles in unique ways to convey their ideas and emotions. It plays a crucial role in guiding the viewer's experience and interpretation of the artwork, making it an essential skill for artists to master.

The composition was utilized in Kandemir's research [14] to optimize the Saliency algorithm. As shown in Figure 3.11, they combined the effect that composition has on the view guidance of a picture and tried to get better results by combining the algorithm of saliency with composition. The big difference between my study and theirs is that the sample is for game conceptual design drawings. Both the combination of colors and the form of the composition are different from photographs. As mentioned above, game concept art is more subjective than real-life photo art and can use richer colors and more specific compositional forms.

## 3.3 Sample Collection

In the chapter dedicated to data collection, I delve into a comprehensive explanation of my approach to gathering the samples used in my research. This chapter is thoughtfully divided into four distinct sections, each serving to illuminate different

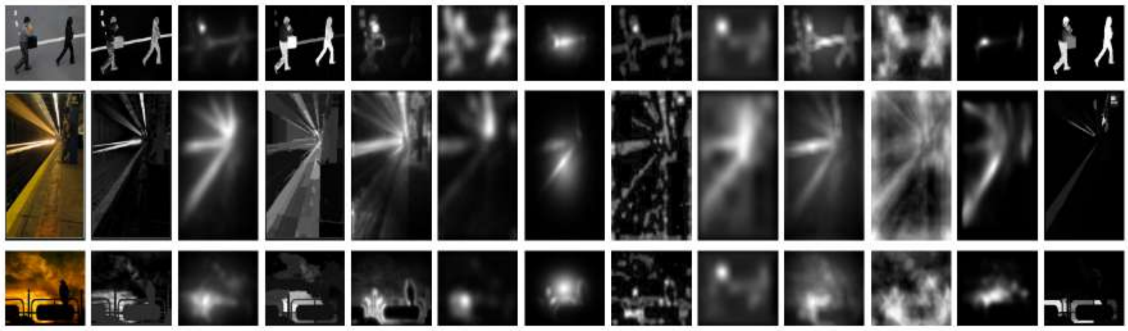

Figure 3.11: The figurative lines in objects and images also guide the viewer's attention.

facets of my sample collection methodology. These sections encompass the platform introduction, art style, sample content, and sample quality, to provide a well-rounded understanding of my data acquisition process.

To initiate my sample collection, I start on the task of sourcing a diverse and representative set of game concept art. In this endeavor, I collect a total of 100 2D game concept artworks. These artworks were collected from Artstation, a globally famous hub for game concept artwork and a primary source of inspiration for artists and enthusiasts alike. Through this collection process, I ensured that my samples were both varied and reflective of the rich diversity present within the world of game concept art.

In subsequent sections of this chapter, I further dissect and analyze these collected samples, shedding light on their respective characteristics, styles, content themes, and the quality criteria employed during their selection. This meticulous approach to data collection forms the cornerstone of my research, as it enables us to draw meaningful insights and conclusions based on a well-defined and representative dataset.

### 3.3.1 Artstation

ArtStation, As shown in Figure 3.12, is an online platform that provides a leading community and showcase space for artists in all creative fields, with a focus on digital art, game concept art, and entertainment industry professionals. It provides a vibrant and dynamic space where artists from around the world can share their work, connect with their peers, and gain exposure in the creative industries.

ArtStation is a center designed by artists for artists. It provides a platform for aspiring and established artists to showcase their work and interact with the global

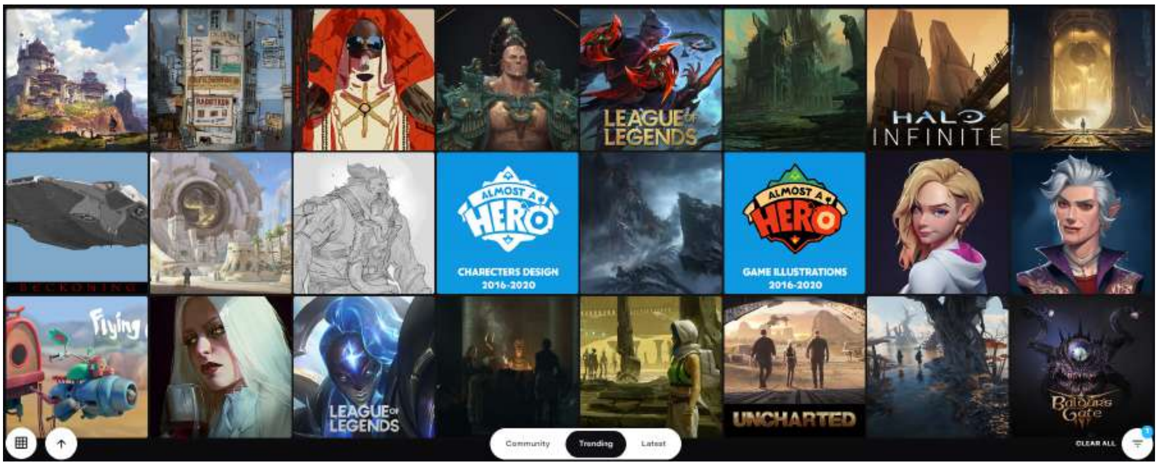


Figure 3.12: The Artstation community

creative community. Designers, including those from many well-known gaming companies, also share their work on the platform. Designers, including those from many well-known gaming companies, also share their work on the platform. It includes concept art of excellent games such as League of Legends, Tomb Raider, and World of Warcraft on this platform. Famous game artist will share their professional artwork on this platform.

ArtStation has become an integral part of the global creative community, bridging the gap between artists and industry professionals, providing a platform for self-expression, and contributing to the growth and development of digital art and design across media and industries.

### 3.3.2 Artstyle

ArtStation encompasses a vast and diverse array of game styles, showcasing an impressive spectrum of creative visions and artistic expressions. Within this expansive platform, one can encounter an eclectic mix of game concept designs, each bearing the unmistakable mark of its creator's personal style. In the data collection for my research, I deliberately refrained from selecting game concept design pieces characterized by an exceedingly personal or idiosyncratic style.

### 3.3.3 Sample Content

ArtStation boasts a vast array of game concept art that spans a multitude of categories, encompassing characters, scenes, equipment, sketches, and a myriad of other creative endeavors. This diverse catalog offers a multitude of imaginative possibilities for artists and enthusiasts alike. However, it's essential to recognize that the concept of the visual center is particularly prominent and relevant when it comes to the game scenes. As such, when embarking on the intricate process of selecting samples for my research, I adopted a discerning criterion to choose the artwork of the game environment as my samples.

### 3.3.4 Sample quality

As practice exercises or learning endeavors, they may not always align with the standards demanded by the professional game industry.

In my endeavor to assemble a sample that truly exemplifies the caliber of artwork sought after in the commercial game industry, I took a meticulous approach. To ensure the highest standards of quality and relevance, I implemented a stringent selection process. Rather than considering all available works indiscriminately, I harnessed a powerful feature within the ArtStation community: the ranking system based on the number of likes.

By leveraging this community-driven metric, I were able to identify and pick the top-ranked works within my chosen category. These top-ranked artworks recognized and appreciated by fellow artists and enthusiasts through their substantial number of likes, served as a reliable indicator of quality and artistic merit. This method of selection allowed us to find the target through the large number of content on ArtStation.

## 3.4 Implementation

The realm of Game art emerges as a fusion of artistic expression and technological innovation. This research builds its foundation upon fundamental principles derived from the principle of painting. The author briefly outlines the principles guiding game concept designers in capturing the audience's attention, starting with the size of color areas. Extensive areas of uniform color, such as a vast expanse of blue sky, seldom pique visual interest. Conversely, small areas featuring vivid, intense colors tend to captivate the viewer's eye. Various composition techniques, including the well-known triangular, symmetrical, and rule-of-thirds approaches, are also pivotal considerations in the pursuit of visual engagement.

As Figure 3.13 illustrates, my method endeavors to restore the three paramount attributes within game concept design. Drawing upon the aforementioned principles,

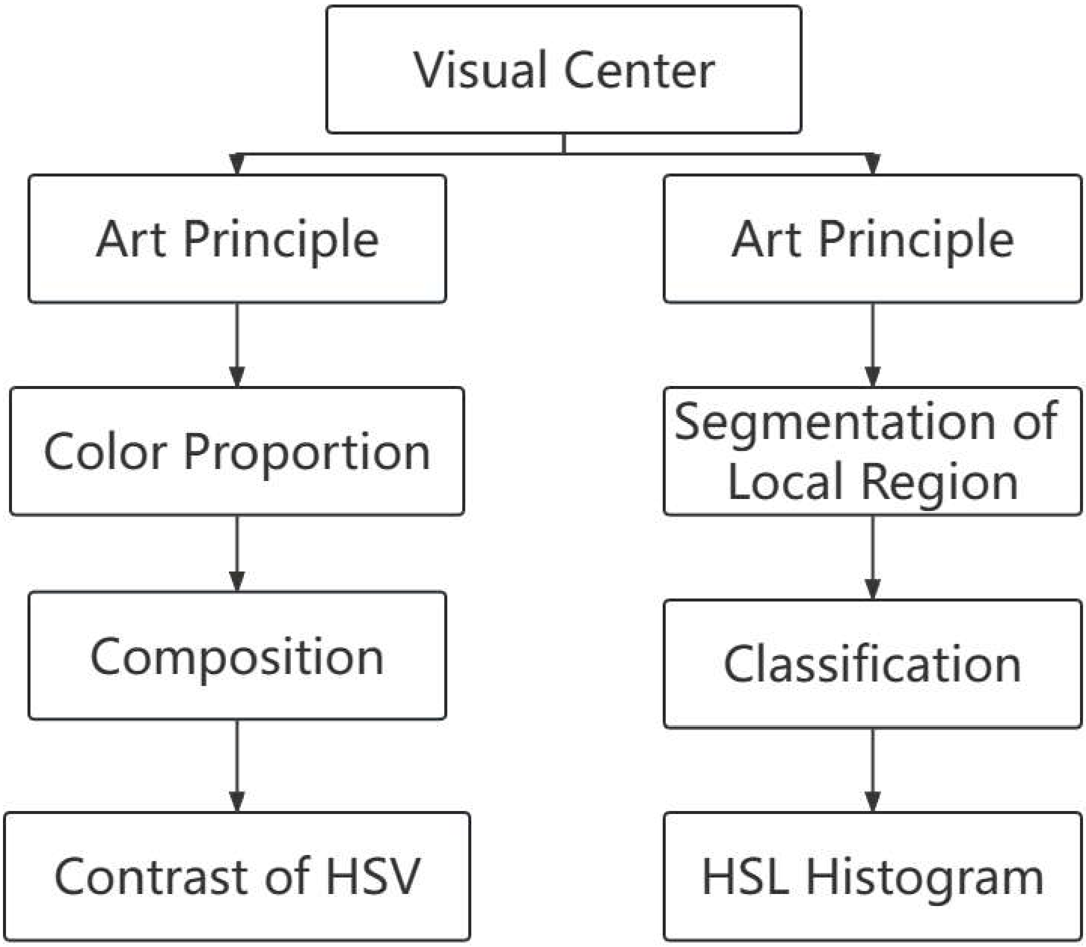


Figure 3.13: match the design principle and algorithms.

I initially employ composition to establish the visual allure of the entire image. Subsequently, I leverage both large and small color areas to amplify the image's rhythm and accentuate the contrast between the visual focal point and non-focal regions. Simultaneously, color proportions, saturation, lightness, and hue undergo substantial variations in these two distinct areas. This approach enables us to uncover the image's visual allure. Grounded in these principles, I have devised a module to fulfill my desired functions. This module comprises four steps, each mirroring essential design principles.

## 3.5 Color Space

The perception of color can be dissected through a range of color spaces, such as HSV, Lab space, CMY, and RGB, among others. In my context, I select the HSV due to its affinity with traditional color theory in painting. In traditional painting, the palette starts with pure, high-brightness base colors, which are mixed in various proportions to yield a spectrum of hues. The color blending process involves the use of contrasting colors to reduce purity and brightness, along with black and white to adjust brightness and diminish purity. The inclusion of the initial single color intensifies both purity and brightness, mirroring the principles of the HSV color space. my algorithm, grounded in the HSV color space, seeks to analyze color and visual focal points in game concept art from a designer's perspective. Additionally, numerous studies have suggested that HSV aligns closely with human perception of color.

For instance, Zhang's research [22] delves into the disparity among color spaces in color palette exploration, contrasting five models: RGB, HSV, LAB, YIQ, and Opponent. While the RGB model proves the quickest, it ranks lower in accuracy compared to the more precise HSV model [22]. Furthermore, Cui [23] notes that, compared to other color spaces, HSV faithfully mirrors human color perception, demonstrating a high degree of concordance with the human eye's subjective understanding of color. This explains why game designers often employ the HSV panel in Photoshop for color selection when crafting game concept art.

## 3.6 Image segmentation

Drawing inspiration from prior research [18] in the field of image processing algorithms, the typical approach involves segmenting images and subsequently subjecting each localized region to analysis and classification to draw meaningful conclusions. This approach serves as a guiding principle for my study. Notably, the aforementioned research [18] demonstrated the successful detection of scenes through a 4*4 segmentation scheme, achieving an impressive 91.4% accuracy rate in object recognition. As shown in Figure 3.14, the adoption of a 4*4 segmentation strategy in my experiment aligns with this methodology, ensuring both algorithmic efficiency and consistently high accuracy.

Figure 3.14: Example of my segmentation method.

## 3.7 Hash string and local region segementation

The perceptual hash algorithm serves as a tool to assess the similarity between two localized regions. This algorithm's primary function involves generating a unique "fingerprint" string for each image, which is subsequently used for comparing the "fingerprints" of distinct images [24]. Within the realm of hash algorithms, three key variants exist Ahash, Phash, and Dhash. Among these, Dhash stands out for its superior combination of accuracy and speed. Consequently, I have opted for Dhash in my analysis, following the steps outlined below to evaluate the similarity of my samples.

Firstly, the initial step entails resizing the local region to 8 pixels * 8 pixels, a process aimed at preserving essential structural and shading information while eliminating intricate details. This resizing also facilitates consistent comparisons, irrespective of variations in local region size.

Secondly, I perform grayscale processing to optimize the overall module's speed.

Thirdly, a comparison of color intensity between adjacent pixels results in assigning them values of "true" (1) or "false" (0) based on intensity differences. Consequently, a 64-value string is generated to encapsulate the information within the local region.

Subsequently, I calculate the similarity between two local regions by comparing their 64-bit hash values obtained through pairwise comparisons. These hash values are recorded separately, enabling us to gauge the similarity between regions comprehensively.

To ensure a thorough comparison among all local regions, each local region is systematically juxtaposed with others.

In the next step, leveraging the hash values acquired earlier, I arrange the hash values denoting the similarity of local regions in descending order. I commence by selecting the two local regions with the highest similarity and placing them into a dictionary. If a subsequent local region matches a previously included one, it is added to the same dictionary. Conversely, if a following local region does not align with any existing dictionary, a new one is created. This process is iterated until all local regions have been appropriately classified.

## 3.8 Data analysis

Ultimately, my process culminates in pinpointing the areas of visual interest based on the frequency of local regions within the dictionary. In Figure 3.15, the horizontal axis represents the HSV values, ranging from 0 to 255, while the vertical axis denotes the count of pixel points. In this illustration, the peaks of HSV values converge at a single point, indicating that the colors within this local region closely resemble each other. Conversely, in Figure 3.16, the peaks of HSV values are dispersed across multiple points, suggesting the utilization of a variety of colors within this local region.

The target area is selected from the dictionary with the fewest occurrences of local regions. In cases where multiple outcomes are detected, adhering to the principles of compositional art, the visual center is typically not placed in the four corners of the image. Assuming the image is segmented into an m*m grid when multiple results arise, my module gives priority to excluding dictionaries containing local regions corresponding to the corners: 0, m-1, m(m-1), m*m-1. For instance, in my study with a 4*4 sample division, my module initially excludes the four local regions positioned at 0, 3, 12, and 15 when dealing with multiple results in the corners.

### 3.8.1 HSV data analysis

Subsequently, I employ the HSV histogram to gauge the extent of color variation within the local region. The non-visual interest area typically exhibits minimal color variation, as depicted in Figure 3.15. In contrast, as shown in Figure 3.16, the local visual interest region displays pronounced changes in hue, saturation, and value. By

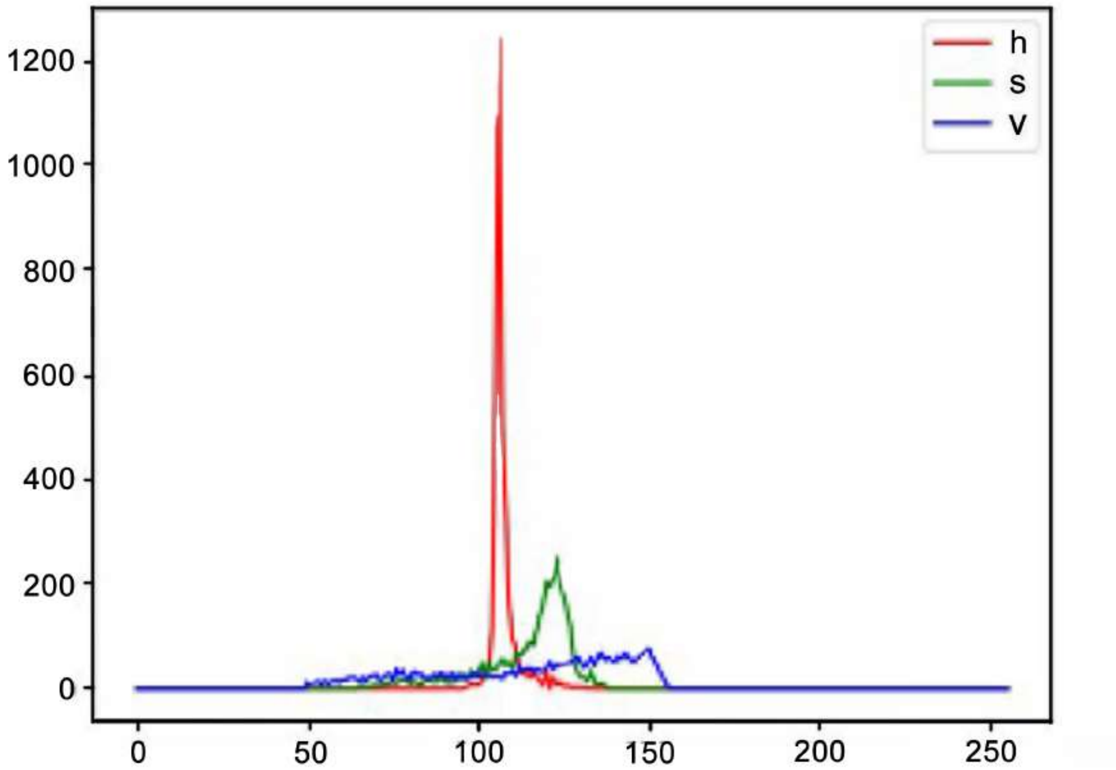


Figure 3.15: HSV histogram in non visual center

comparing these two images, I can distinctly differentiate between regions of visual interest and regions lacking visual appeal.

After completing the above experimental steps, I have concluded. I analyzed a sample of 100 images and obtained their visual centers through an algorithm. The concept of a visual center is broad and subjective. To verify the validity of my conclusion, I conducted an evaluation experiment.

### 3.8.2 Experiment and data collection

I mentioned that I applied the two Saliency methods mentioned in the related work section to my samples. In the related work, I mentioned three Saliency methods. Among them, the motion saliency method is designed for videos and is not applicable to my study. I applied the Static Saliency and Objectness Saliency methods, respectively, to my samples. A comparison of the conclusions reveals that my method has significantly improved the efficiency of recognizing the visual center of game conceptual design art.

Firstly, the objectness saliency method is designed for detecting the visual centers

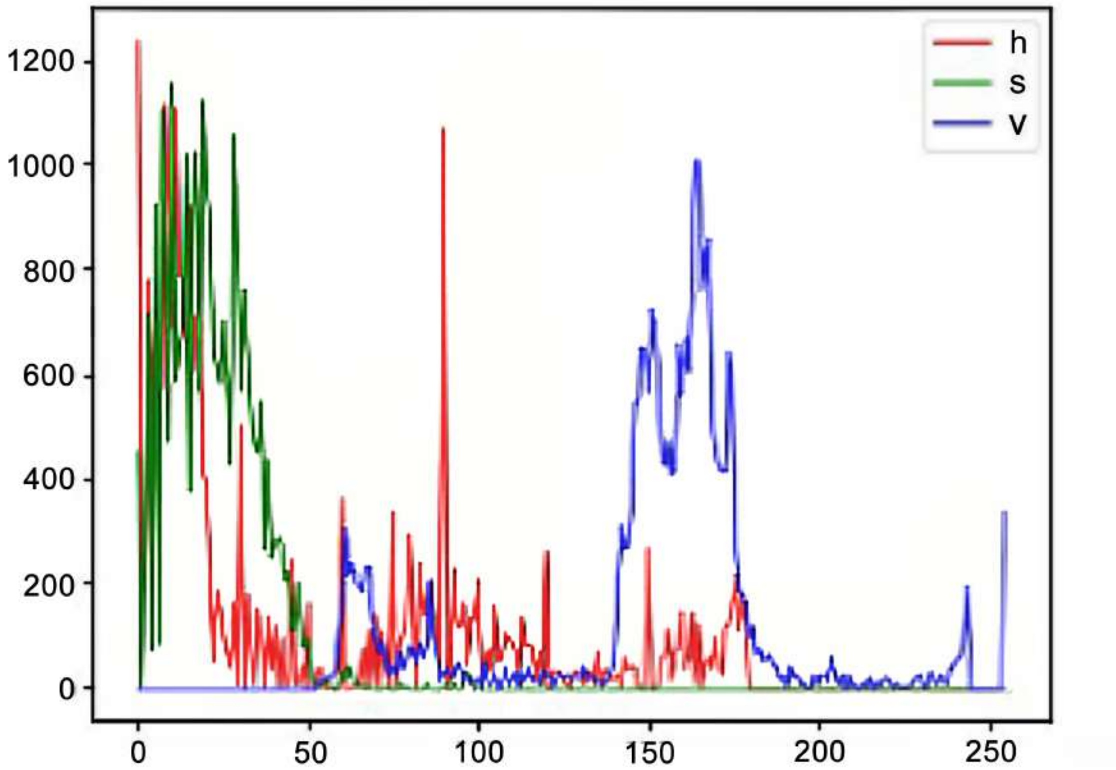


Figure 3.16: HSV histogram in visual center

of objects. It is typically utilized on similar MSRA samples where there are significant single objects as the subject matter. Therefore, objectness saliency can perform well in such cases. However, in game concept art, a single artwork often features more than one object on the screen. Consequently, the objectness saliency method does not perform well in the context of game concept art.

Static saliency, on the other hand, highlights areas where the pixels are changing, which can be effective in certain game concept artworks. These artworks are usually relatively simple in terms of color composition. However, when the color combinations become complex, the static saliency method struggles to accurately identify areas in the center of the visual field. In such cases, the method tends to label most of the image as salient.

Saliency research conventionally relies on the MSRA sample set, comprised of images characterized by distinct subject objects. This dataset serves as a robust benchmark for evaluating the accuracy of saliency methodologies, primarily in terms of subject-object recognition. However, the intricacies of game concept art pose a challenge, as these images often feature complex and multifaceted objects, rendering


Figure 3.17: The picture above is a recording of one participant. The image below is an example of how I put together the conclusions of fifty participants.

traditional saliency assessment methods less suitable for ensuring accuracy. Consequently, I adopted a novel experimental approach tailored to the nuances of my study. The experimental methodology is outlined as follows:

In my experimental setup, I engaged the participation of 50 individuals, each entrusted with the task of identifying the visual center within every image in my dataset. To facilitate this, I designed a user-friendly interactive program using Python, enabling participants to pinpoint the visual center of each image with a simple click. These collective responses were subsequently amalgamated into a single comprehensive image. As exemplified in Figure 3.17, the regions where the dots densely clustered were indicative of the visual centers as perceived by the participants.

Upon establishing the visual centers for all 100 images, my analysis pivoted to a comparative phase. I scrutinized and contrasted the visual centers generated by my algorithm with those derived from two prominent saliency methodologies. Additionally, I took into account the visual center areas identified by the participants, thus offering a multifaceted evaluation.

Furthermore, within the realm of my sample analysis, I incorporated two saliency methods to enrich my perspective. While the availability of open-source code for all saliency methods posed a challenge, I successfully identified three methodologies referenced in related work. Regrettably, the motion saliency method, tailored for video analysis, proved unsuitable for my study. Instead, I implemented the objectness saliency method and the static saliency method on my image samples, as visually depicted in Figure 3.18. These deliberate choices aimed to expand my analytical scope and provide a comprehensive evaluation of visual center determination within the context of game concept art.


Figure 3.18: The result from object saliency method and static saliency method

## 3.9 Results

I conducted a comprehensive comparison of the results derived from my evaluation experiment, which encompassed 100 diverse samples. The outcomes of this analysis revealed noteworthy disparities among the different saliency methods employed. Notably, As shown in Figure 3.19, the objectness saliency method exhibited a relatively limited capacity, accurately detecting only 18 out of the 100 samples. Similarly, the static saliency method fared better but still fell short, correctly identifying 46 of the samples. In stark contrast, my custom methodology emerged as the frontrunner, boasting a significantly higher accuracy rate by precisely detecting 67 out of the 100 samples.

These findings underscore the efficacy of my approach in the precise identification of the visual center area within the intricate realm of game concept art. Given the inherent complexity of elements within game concept art, the objectness saliency method grapples with limitations in accurately pinpointing the visual center area.

On the other hand, the static saliency method primarily relies on identifying regions characterized by pixel variations, exhibiting superior performance when compared to the objectness saliency method within the context of game concept art.

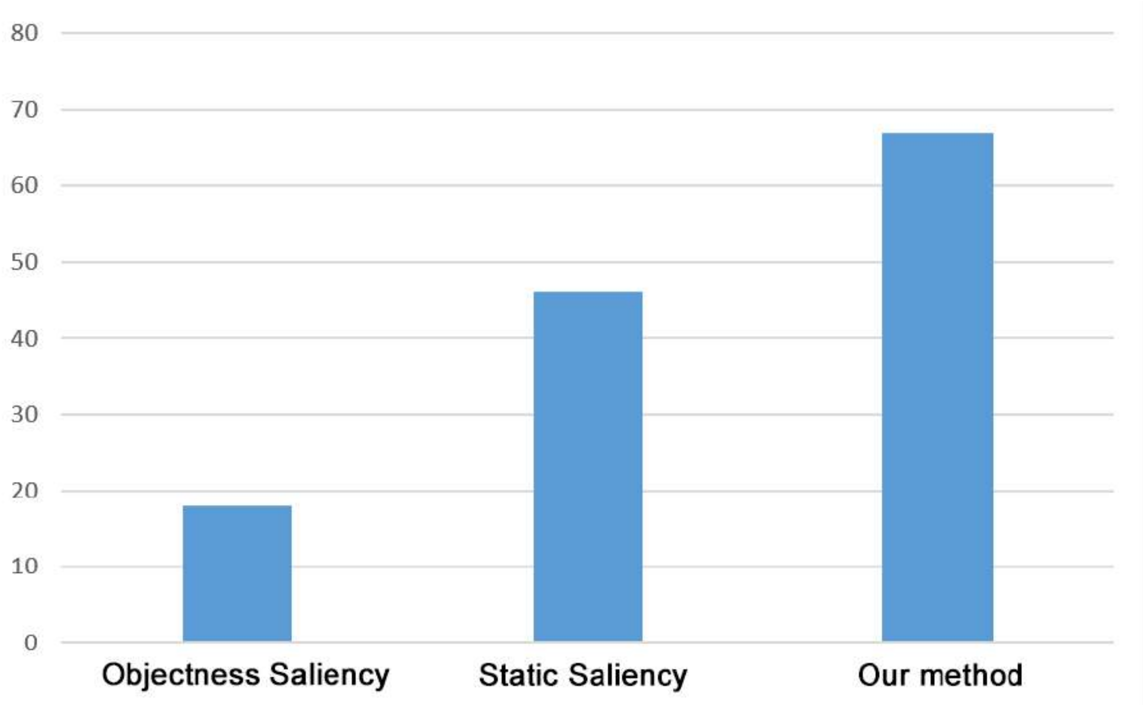


Figure 3.19: Compare the visual center analysis effects of three methods on game concept art.

However, it's essential to note that the static saliency method is not without its shortcomings, particularly when applied to certain instances of game concept art. In cases where the entire image showcases pixel variations, the static saliency method tends to mark the entire picture with white, failing to effectively highlight the specific visual center area. In contrast, my proposed methodology represents a notable advancement, surpassing the static saliency method by a substantial margin of 45.65%. These findings underscore the effectiveness of my approach in enhancing the accuracy of visual center detection within the intricate and dynamic domain of game concept art.

### 3.9.1 objectness saliency result

Through my experiments, I found the flaws of objectness saliency when using game concept design drawings as samples. In previous studies, objectness saliency has been able to recognize the main objects in a picture very well. However, unlike the photo samples in the previous saliency, some of them do not have main objects in the pictures, such as grand scenes. Moreover, in some of the game concept images, there are multiple objects at the same time, such as characters, monsters, weapons, etc. appearing in one image at the same time. This feature of game concept art makes objectness saliency difficult to identify the visual center of the game concept art.

Even if there is a single object in some game concept art, the concepts of visual center and object are very different. A subject is an object, while a visual center is an area. A region may contain multiple objects. This is the reason why objectness does not work well in game concept design.

### 3.9.2 Static saliency result

The results show that static saliency can find the visual center region relatively better than objectness saliency. Static saliency is also a saliency analysis method for pixel variation. However, static saliency also has its drawbacks for game concept art. Static saliency analyzes the whole picture in terms of its pixel changes, which means that it will analyze the whole picture as long as the pixel changes. This means that the image will be labeled as a significantly changed area if there is a pixel change. Complex color changes in game concept art are not only in the visual center, but also in the non-visual center. This leads to the fact that static saliency can find areas of pixel change to a certain extent, but the range of conclusions obtained is too large. So much so that static saliency doesn't show the visual center very well.

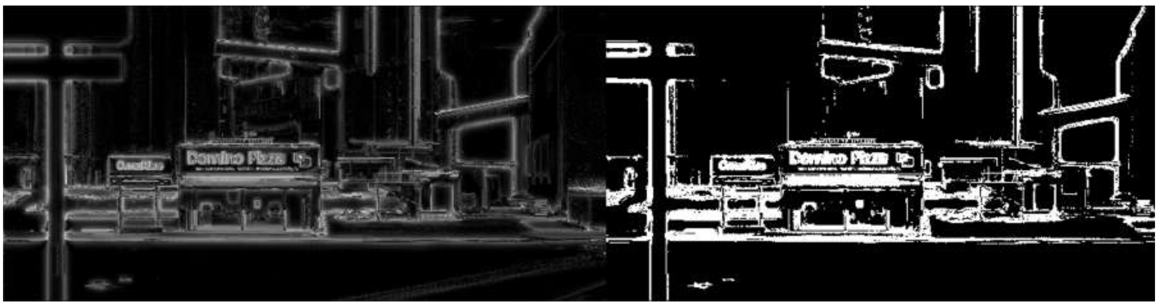

Figure 3.20: The result of static saliency

For example, as shown in Figure 3.20, although static saliency has a better performance compared to objectness saliency, the analysis of static saliency for the whole image tends to make most of the content of the image belong to the salient region. My method cuts and categorizes the image to narrow down the visual center.

## 3.10 Discussion

This chapter endeavors to develop a visual center detector, starting from the creative thinking processes of artists and focusing on the realm of game concept art. This comprehensive algorithm incorporates fundamental painting principles and employs them to simulate the artistic process, facilitating the detection of visual points of interest within the artwork. In doing so, this chapter aspires to chart new territories within the domain of game concept art, concurrently laying the groundwork for forthcoming studies in the fields of game design and painting. This innovative module encompasses the fundamental principles of painting, designed to simulate the creative process itself, all in the pursuit of identifying and detecting visual points of interest within images.

However, it's important to acknowledge that this research, like any endeavor, is not without its limitations. Firstly, the extent of segmentation applied can significantly influence the results. In my preliminary testing, both excessive and insufficient levels of segmentation led to inaccuracies in the outcomes. Secondly, game concept art often features various elements, such as characters, animals, machinery, and monsters, all integral to the design. These elements carry varying degrees of visual interest, and if they are inadvertently included during the segmentation phase, they may receive undesirably low weighting during the analysis, potentially resulting in misdetection. Finally, artworks with a dark art style, characterized by minimal hue, saturation, and value (HSV) changes, present challenges for detection using this method.

In my forthcoming research endeavors, I endeavor to address these challenges and broaden my horizons. By adopting a comprehensive approach, I aim to encompass a wide spectrum of art types and themes, and subsequently, refine my sample classifications. Firstly, I will persistently fine-tune and optimize my algorithm, with a sharp focus on enhancing both accuracy and precision. Secondly, I will embark on a thorough analysis of the color variations within visual interest areas and non-visual center areas, aiming to uncover and understand the intricate relationships between color usage patterns and the perception of visual centers. Through these ongoing efforts, I aspire to enrich my understanding of the dynamic interplay between art, aesthetics, and visual attention, contributing to the evolution of both the field of visual attention and the broader realms of art and game design.

## 3.11 Chapter Conclusions

In this section, I have successfully completed the initial step of my overarching research objective, which is around the detection of the visual center region within game concept art. In the introductory section, I introduced the concept of the visual center, emphasizing its critical role in the game concept art. I elucidated the distinctive characteristics of game concept art as the target of my research. Furthermore, I elucidated the distinctions between game concept artwork and other visual mediums such as photographs and movies.

Moving on to the related work section, I provided an extensive overview of various saliency methods that share similarities with my research. As saliency methods have evolved, they have proven highly effective in recognizing specific objects and edges. However, I discovered that traditional saliency approaches often yield suboptimal results when applied to the unique context of game concept art. Concurrently, I delved into an exploration of the "bag of features" concept within this section, leveraging it as a reference for designing my algorithm.

My research also delves into the meticulous selection of sample sources and outlines the rationale guiding our choices. I specifically opted for scene-related game concept art to comprise my sample dataset, while actively avoiding artworks with pronounced personal characteristics.

Subsequently, I provided an in-depth exposition of my algorithm's design process. I identified three primary strategies employed by the way designers emphasize the visual center within the game concept art. To simulate these approaches, I amalgamated the "bag of features" method with hash string techniques, offering solutions for the first two strategies. For the final approach, I employed HSV (Hue, Saturation, and Value) analysis. Through this comprehensive process, I successfully derived the visual center of the image.

In pursuit of a comprehensive validation of research methods capable of cross-sectional saliency comparison, this chapter embarks on a rigorous evaluation experiment. Preceding the experiment, an innovative interactive tool was meticulously crafted, affording participants the ability to engage directly with the images, intuitively identifying what they perceived as the central point of their visual focus. My outreach successfully garnered the participation of a diverse cohort of 50 individuals, who were tasked with pinpointing the visual center within a curated selection of one hundred sample images. The outcome of this concerted effort was then synthesized into a singular illustrative diagram, providing a clear representation of the region identified as the visual center.

Subsequently, my research ventured into the realm of open-source saliency methods, wherein two distinct approaches were applied to the same set of image samples. A meticulous comparative analysis ensued, contrasting my experimentally determined visual centers with the conclusions derived from the two saliency methods.

In the concluding section, I embarked on a comprehensive summary and analysis of my findings. This analysis encompassed a comparative evaluation of my algorithm against traditional saliency algorithms and approaches. I conducted experiments utilizing both my algorithm and conventional saliency algorithms on a sample dataset of game concept art. The outcome of this comparative analysis unequivocally demonstrated the superior performance of my algorithm in effectively identifying the visual center in comparison to existing saliency methods. I encapsulate the inherent strengths of my algorithm, underlining its advantages, while also conscientiously addressing potential pitfalls and challenges that may arise in its application.

I undertook an extensive examination of the outcomes stemming from my comprehensive evaluation experiment, which encompassed a diverse set of 100 samples. The results of this analysis unveiled conspicuous disparities among the various saliency methods that were employed. Notably, the objectness saliency method demonstrated a rather restricted capability, successfully identifying only 18 out of the 100 samples. In a similar vein, the static saliency method exhibited a better performance but still fell short, accurately pinpointing 46 of the samples. In stark contrast, my proprietary methodology emerged as the frontrunner, boasting a significantly superior accuracy rate by precisely detecting 67 out of the 100 samples.

# Chapter 4

# Color combination in game concept art

## 4.1 Introduction

The exploration of color combinations has been a timeless endeavor in the realms of painting and visual design, a quest that unravels the intricate interplay of hues, saturation, and brightness. These three-dimensional attributes of colors render the art of combining them a complex and multifaceted undertaking. Over time, the aesthetics governing color combinations have undergone a fascinating evolution, mirroring shifts in artistic sensibilities and societal preferences.

Notably, an array of analogous investigations into color combinations have been conducted across diverse domains. For instance, Jahanian's research [2] delved into the realm of logo design, meticulously analyzing color combinations and their proportions within this specialized context. Distinct from this line of inquiry, my study occupies a unique niche, with a primary focus on the intricate world of game concept design.

Scholars and researchers have persistently sought to unravel the enigma of color from a multitude of perspectives, constantly innovating methodologies and uncovering novel patterns in color combinations. Take, for instance, Yamazaki's investigation [25], which delved into the interplay between Kansei (emotional responses) and color, or Hu's pioneering study [26], which ingeniously combined familial factors and rhythm span to establish a fresh approach to color selection.

What sets my research apart is its unswerving dedication to the dynamic domain of game concept art, a domain that wields immense influence within the gaming industry [27]. In the realm of game concept art, colors serve multifaceted roles, defining unique visual styles, directing viewers' attention, and creating striking contrasts that captivate the imagination. While many insights gleaned from prior research on color combinations can be readily applied to game concept design, a crucial distinction emerges when I consider the treatment of color within these artworks. This distinction hinges on the differentiation between the visual center and the non-visual center, an aspect that has often been overlooked in previous studies.

In my prior investigation, I introduced a crucial module designed to distinguish between these two distinct regions within 2D game concept art. Approaching the subject from the perspective of an artist, my current study embarks on a meticulous analysis of color transformations and combination patterns within the specific domains of the visual center and non-visual center. By doing so, I aim to offer a more nuanced understanding of how color combinations are employed in the field of game design, a nuanced perspective that can potentially enhance the artistic prowess of game designers during the creative process.

In essence, my anticipations are twofold: firstly, that my findings will shed new light on the intricate world of color combinations within game concept art, and secondly, that these insights will serve to empower game artists, providing them with a more sophisticated toolkit for leveraging the magic of color in their creative endeavors.

My research endeavors to delve into the captivating realm of contemporary game concept art, which intricately weaves itself into the fabric of present-day aesthetics. Contemporary aesthetics, a realm situated at the intersection of philosophy and art criticism, seeks to unravel the essence, principles, and theories underpinning beauty and artistic expression within the context of my current era and cultural milieu. A broader perspective on aesthetics inquires into the very essence of beauty and the factors that shape my perception and appreciation of art and beauty. In this quest, it does not overlook the profound influence of contemporary cultural, social, political, and technological dynamics on my evolving aesthetic sensibilities. Notably, as technology advances at a breakneck pace, contemporary aesthetics also scrutinizes how digital media, virtual reality, and other technological innovations have profoundly transformed the creation, experience, and interpretation of art.

Distinguishing my study from its predecessors are three pivotal aspects. The first divergence lies in the focus of my investigation, which diverges significantly from the realms of photography and graphic design. Game concept artwork emerges as a distinct entity, marked by its bold and intricate utilization of colors. This becomes especially pronounced in the realm of game scene design, where game concept art deftly harnesses the power of color contrasts and subtle variations to create immersive visual experiences.

The second unique facet of my research centers on the concept of the visual center. Unlike previous research, which often scrutinized color information across the entire image, my study acknowledges the paramount importance of understanding the visual center for game concept designers. This recognition stems from the realization that the rules and methodologies governing the use of colors in the visual center versus the non-visual center areas vary significantly. This focus on distinguishing between these two spheres is a distinctive feature absent in analogous studies, such as those concentrated on photography or visual design.

The third salient point underscores the often-overlooked significance of color proportion in similar studies investigating color combinations. The proportion of color within an image wields considerable influence over its overall visual impact and can also significantly alter the intensity of color contrasts. This nuanced exploration of color proportion adds an enriching dimension to my research, setting it apart from its counterparts in the field of color combination studies.

## 4.2 Related Work

### 4.2.1 color combination

In recent years, there have been a lot of innovative methodologies aimed at advancing the field of color palette analysis. One example is Chang's work [28]. In this study, Chang introduced an interactive tool designed to democratize color palette creation by enabling non-professionals to enhance color photographs using a user-friendly palette generator. Similarly, As shown in Figure 4.1, Kumar's research [8] made significant strides by applying the k-means clustering algorithm to extract color palettes, offering a fresh and systematic approach to this area of study.

Despite the valuable contributions of Chang and Kumar to the field, my research distinguishes itself in several key ways. Firstly, my study pivots towards the domain of game concept artwork, a realm known for its intricate and exaggerated use of color and shape. In this context, I confront a broader and more complex spectrum of color combinations, necessitating unique analytical approaches.

Moreover, my investigation places a particular emphasis on the analysis of color proportion. I seek to delve deeper into how colors interact and complement each other, with a specific focus on discerning disparities between the visual and non-visual aspects of these combinations. my research promises to unveil novel insights that extend beyond the scope of previous studies, ultimately enriching my understanding of the intricate world of color palettes.


Figure 4.1: Recent research has noted the importance of color proportions. However, it is not difficult to see from the figure that the color combinations of photos and game concept design drawings are very different, and the concept of visual center has not been involved in previous studies.[8]

### 4.2.2 Colorization

Another related research is Colorization. Research on colorization covers a wide spectrum of disciplines, from computer graphics to aesthetics and cultural studies. One key area involves developing techniques to add color to black-and-white images or videos. These methods often employ algorithms that analyze image context, textures, and semantics to accurately infer and apply colors[29]. This kind of research usually uses the gradient map for colorization. The gradient map is an image editing technique that assigns colors to different brightness levels in an image, often used for colorization purposes. It works by mapping a gradient of colors onto a grayscale image based on its tonal values. End of this chapter, we also use the gradient map to apply my result to colorization.

Another significant facet is the integration of deep learning and AI in colorization. Advanced neural network models are being explored to understand and predict colors based on extensive datasets. This approach enables the automated or semi-automated colorization of images by recognizing patterns and contextual cues.

## 4.3 Method

### 4.3.1 Proposed method

My research adheres to the systematic framework illustrated in Figure 4.2, a well-structured sequence of procedures meticulously designed to unravel the intricacies of my study. In its initial phase, I harnessed the powerful tool of image segmentation

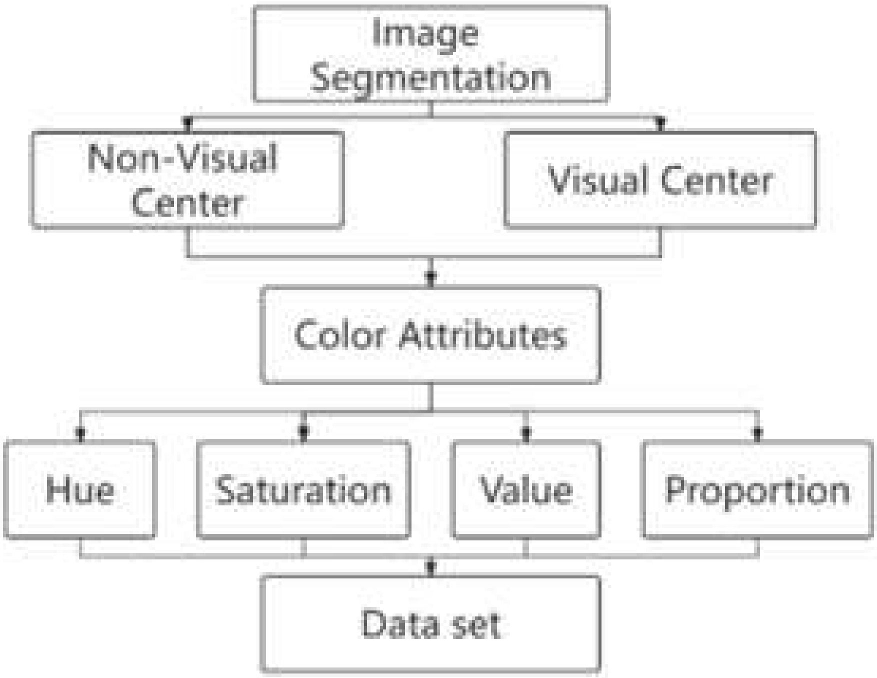


Figure 4.2: framework of color combination analysis

to meticulously partition the image into distinct regions, most notably distinguishing between the visually prominent center and the more peripheral non-visual regions. A comprehensive exposition of this foundational step can be found in my prior study [30], where I expound upon the nuances and techniques employed in this pivotal process.

Moving on to the second step, I start a journey into color analysis. Here, I employed the robust HSV (Hue, Saturation, Value) color space to categorize the colors in my segmented regions. These colors were systematically classified into ten distinct intervals: black, white, grey, red, orange, yellow, green, cyan, blue, and violet. This meticulous categorization not only facilitated a structured analysis but also laid the foundation for my subsequent investigations into color proportions, contrasts, and their collective impact on the overall aesthetic composition.

My research methodology is based on an artistic perspective, where I use a sophisticated algorithmic framework to imitate the design process in creating a work of art. In this purpose, I found the HSV (Hue, Saturation, Value) color space to be the most fitting choice, mirroring the traditional color mixing methods observed in various artistic methods such as oil painting, watercolor painting, and other conventional materials. These traditional techniques often rely on the primary colors of red, blue, and yellow to craft a wide array of hues. Adjustments to color saturation are achieved through the use of complementary colors, while the manipulation of brightness is accomplished using black and white.

The selection of the HSV color space was a thoughtful choice, as it mirrors the very foundations of traditional art and provides a framework for my analysis. These findings were meticulously recorded and organized into a comprehensive table, effectively capturing the percentage distribution of different color intervals.

Notably, this thorough analysis served to reaffirm the consistency of my previously established visual center. my examination of the data presented in the table enabled us to draw definitive conclusions, shedding light on the nuanced interplay of colors within artworks and contributing to a deeper understanding of the creation process.

### 4.3.2 Visual center detection

In the preliminary stages of my investigation, a clear differentiation was established between the visual centers and non-visual centers in the game concept art. I employed a meticulous segmentation strategy, which effectively subdivided the concept art into 16 discernible and self-contained regions, which I have formally labeled as "local regions." This method was inspired by the insightful work of Wang [18], whose research has convincingly advocated for the utilization of a 4x4 grid segmentation that is good enough for recognition tasks. Each local region summarizes both the typical visual center local region and the corresponding non-visual center local region, thereby affording us a comprehensive understanding of the interplay between these critical facets of the game concept art.

At the start of my experimental endeavor, I engaged in an exploration of various segmentation methodologies, meticulously evaluating options that ranged from 2x2 to 6x6 divisions. I discovered that the 2x2 and 3x3 segmentation methods while having the advantage of simplicity, resulted in local regions that were too expansive. This enlargement posed a substantial challenge in precisely detecting the visual center in game concept art. On the other side, when employing segmentation sizes of 5x5 or larger, the local regions were rendered excessively diminutive. Each local region does not have enough color change in there. That also causes difficulty in detecting visual center

In light of these deliberations and alignment with Wang's comprehensive research survey, I opted for the 4x4 segmentation approach as my experimental framework. This choice struck an optimal balance, providing sufficiently discernible local regions

| | 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 4.3: HSV color interval

that facilitated an accurate determination of visual centers, while still offering a granular level of detail necessary for a comprehensive and nuanced analysis of color changes and design elements within each of these reasonably sized segments.

### 4.3.3 HSV Color interval

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

Figure 4.3 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 [31]. For my specific objectives, I 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. my method is designed based on the HSV color space that aims to analyze color in game concept art from the perspective of

Table 4.1: Typical

| | black | gray | white | red1 | red2 | orange | yellow | green | cyan | blue | purples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 97.13 | 0.07 | 0 | 0 | 0 | 0 | 0.02 | 2.92 | 0.11 | 0 |
| 2 | 0 | 90.67 | 0 | 0 | 0 | 0.01 | 0.02 | 0.05 | 10.33 | 0.12 | 0 |
| 3 | 0 | 96.22 | 0.14 | 0.07 | 0 | 1.27 | 0.04 | 0.02 | 2.10 | 0.88 | 0 |
| 4 | 0.26 | 96.17 | 0 | 0.33 | 0.10 | 0.36 | 0.03 | 0 | 2.02 | 1.07 | 0.26 |
| 5 | 0.00 | 97.22 | 0.15 | 0.06 | 0.06 | 2.20 | 0.16 | 0.04 | 0.04 | 0.53 | 0.00 |
| 6 | 0 | 85.33 | 0.11 | 0.09 | 3.58 | 9.62 | 0.17 | 0.01 | 1.45 | 0 | 0.69 |
| 7 | 0.74 | 58.18 | 0.90 | 12.68 | 5.43 | 9.37 | 0.45 | 0.01 | 0.15 | 12.44 | 1.77 |
| 8 | 0.35 | 70.37 | 0.02 | 10.61 | 1.96 | 11.12 | 0 | 0 | 0.01 | 6.01 | 1.22 |
| 9 | 0.44 | 20.54 | 0 | 0.27 | 0.01 | 0.64 | 0 | 0 | 4.1 | 74.73 | 2.08 |
| 10 | 1.22 | 31.09 | 0 | 3.32 | 0.37 | 4.63 | 0.06 | 0.01 | 3.18 | 57.71 | 0 |
| 11 | 1.24 | 36.18 | 0 | 6.37 | 0.74 | 1.71 | 0.01 | 0 | 0.69 | 54.08 | 2.02 |
| 12 | 3.32 | 32.3 | 0 | 0.09 | 0.01 | 3.4 | 0.06 | 0.01 | 0.45 | 58.46 | 4.19 |
| 13 | 0.29 | 0.34 | 0 | 0 | 0 | 0 | 0 | 1.74 | 7.7 | 87.35 | 2.71 |
| 14 | 0.33 | 0.59 | 0 | 0 | 0 | 0 | 0 | 1.87 | 14.53 | 79.88 | 3.02 |
| 15 | 0.14 | 4.16 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.49 | 94.84 | 0.7 |
| 16 | 1.5 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.52 | 95.3 | 2.92 |

a designer. Zhang's research [22] 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 [22]. Cui [23] 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, I chose to use HSV as my color space. I am converting the color values into color labels based on the HSV range.

Firstly, I was tasked with determining the proportion of color pixels that exhibited visual similarity within the central visual area of interest. Secondly, it meticulously assessed the proportion of analogous colors present within the non-visual center area, all across the gamut of my carefully partitioned local regions. I summarize the result in the table, as illustrated in Figure 4.3.

For my study, I collected a big set of 100 really good examples of game art. I got these from a cool art community called Artstation[9]., known for having awesome and original game art. I then took each of these samples and split them into 16 smaller parts, giving us a total of 1600 parts to look at. This took a lot of effort but helped us find interesting color patterns, which I carefully wrote down for my research.

I employ a well-crafted Python code to count and quantify the proportion of each

Table 4.2: Monochrome

| | black | gray | white | red1 | red2 | orange | yellow | green | cyan | blue | purples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 98.72 | 0.59 | 0 | 0.07 | 0 | 0.76 | 0.01 | 0 | 0.01 | 0 | 0 |
| 2 | 98.19 | 1.35 | 0 | 0.17 | 0 | 0.57 | 0 | 0 | 0 | 0 | 0 |
| 3 | 98.45 | 0.01 | 0 | 0.55 | 0 | 1.26 | 0 | 0 | 0 | 0 | 0 |
| 4 | 98.18 | 0 | 0 | 1.07 | 0 | 0.82 | 0.02 | 0.01 | 0 | 0 | 0 |
| 5 | 66.85 | 16.16 | 0 | 3.74 | 0.16 | 16.01 | 0.09 | 0.05 | 0.01 | 0 | 0 |
| 6 | 25.44 | 73.52 | 0.18 | 0.39 | 0.01 | 1.62 | 0 | 0 | 0 | 0.05 | 0.17 |
| 7 | 69.94 | 7.88 | 0 | 11.09 | 0.22 | 14.07 | 0 | 0 | 0 | 0 | 0 |
| 8 | 87.32 | 0 | 0 | 6.54 | 0 | 6.81 | 0.01 | 0 | 0 | 0 | 0 |
| 9 | 22.37 | 27.07 | 1.55 | 25.21 | 0.13 | 24.87 | 0.05 | 0.14 | 0.07 | 0.02 | 0.2 |
| 10 | 0 | 86.92 | 9.58 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0.71 |
| 11 | 30.75 | 20.08 | 0.01 | 38.69 | 0.68 | 14.69 | 0 | 0.01 | 0.02 | 0 | 0.01 |
| 12 | 71.98 | 0.01 | 0 | 8 | 0 | 21.41 | 0.01 | 0 | 0 | 0 | 0 |
| 13 | 29.53 | 4.6 | 0.3 | 44.67 | 0.14 | 22.68 | 0.17 | 0.24 | 0.12 | 0.03 | 0.02 |
| 14 | 5.39 | 48.19 | 1.98 | 29.27 | 1.16 | 11.46 | 0.09 | 0.14 | 0.45 | 0.29 | 1.25 |
| 15 | 23.41 | 4.41 | 0 | 46.02 | 0.15 | 27.67 | 0.09 | 0.11 | 0.02 | 0 | 0 |
| 16 | 61.6 | 0 | 0 | 18.3 | 0 | 21.72 | 0.02 | 0 | 0 | 0 | 0 |

Table 4.3: balance

| | black | gray | white | red1 | red2 | orange | yellow | green | cyan | blue | purples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 98.72 | 0.59 | 0 | 0.07 | 0 | 0.76 | 0.01 | 0 | 0.01 | 0 | 0 |
| 2 | 98.19 | 1.35 | 0 | 0.17 | 0 | 0.57 | 0 | 0 | 0 | 0 | 0 |
| 3 | 98.45 | 0.01 | 0 | 0.55 | 0 | 1.26 | 0 | 0 | 0 | 0 | 0 |
| 4 | 98.18 | 0 | 0 | 1.07 | 0 | 0.82 | 0.02 | 0.01 | 0 | 0 | 0 |
| 5 | 66.85 | 16.16 | 0 | 3.74 | 0.16 | 16.01 | 0.09 | 0.05 | 0.01 | 0 | 0 |
| 6 | 25.44 | 73.52 | 0.18 | 0.39 | 0.01 | 1.62 | 0 | 0 | 0 | 0.05 | 0.17 |
| 7 | 69.94 | 7.88 | 0 | 11.09 | 0.22 | 14.07 | 0 | 0 | 0 | 0 | 0 |
| 8 | 87.32 | 0 | 0 | 6.54 | 0 | 6.81 | 0.01 | 0 | 0 | 0 | 0 |
| 9 | 22.37 | 27.07 | 1.55 | 25.21 | 0.13 | 24.87 | 0.05 | 0.14 | 0.07 | 0.02 | 0.2 |
| 10 | 0 | 86.92 | 9.58 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0.71 |
| 11 | 30.75 | 20.08 | 0.01 | 38.69 | 0.68 | 14.69 | 0 | 0.01 | 0.02 | 0 | 0.01 |
| 12 | 71.98 | 0.01 | 0 | 8 | 0 | 21.41 | 0.01 | 0 | 0 | 0 | 0 |
| 13 | 29.53 | 4.6 | 0.3 | 44.67 | 0.14 | 22.68 | 0.17 | 0.24 | 0.12 | 0.03 | 0.02 |
| 14 | 5.39 | 48.19 | 1.98 | 29.27 | 1.16 | 11.46 | 0.09 | 0.14 | 0.45 | 0.29 | 1.25 |
| 15 | 23.41 | 4.41 | 0 | 46.02 | 0.15 | 27.67 | 0.09 | 0.11 | 0.02 | 0 | 0 |
| 16 | 61.6 | 0 | 0 | 18.3 | 0 | 21.72 | 0.02 | 0 | 0 | 0 | 0 |

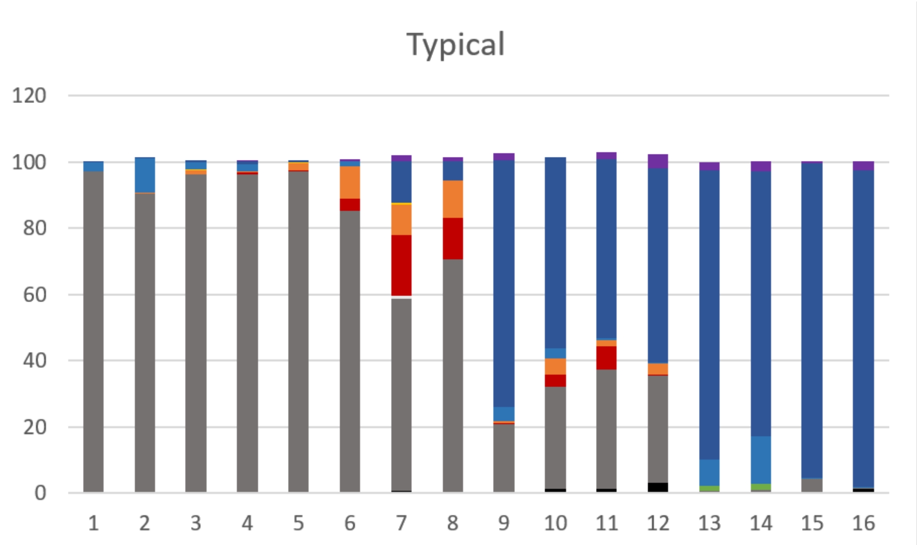


Figure 4.4: Histogram of all the colors

color present within every local region separately. This computational process provided us with precise insights into the color composition of each region. For instance, consider the first local region, where the proportion of orange color is designated as 0. This numerical value unequivocally signifies that there is an absolute absence of orange color within that particular local region, leaving no room for ambiguity or uncertainty.

In my pursuit of comprehending and deriving meaningful insights from the voluminous data acquired, I embarked on a crucial step – the conversion of my data into visually informative histograms. Histograms vividly portray the distribution of colors within the individual local regions I dissected. The x-axis in this graphical representation corresponds to each distinct local region, while the y-axis succinctly encapsulates the proportions of black, white, gray, and other colors present within each of these regions.

What makes my analysis particularly illuminating is that it employs two distinct approaches to color analysis, as visible in the comparison of Figures 4.4 and 4.5. In Figure 4.4, I encompass the entire spectrum of colors, including black, white, and gray. In contrast, Figure 4.5, excludes black and white from the analysis. The visual center exhibits a greater intensity of color variation, lending it a vibrant and dynamic quality. Conversely, the non-visual center area tends to be dominated by a single, dominant color, indicative of its comparatively subdued and less diverse color palette.

I perform a comprehensive analysis, consolidating together the observed patterns of color combinations. This combination serves as the keystone to my study, allowing

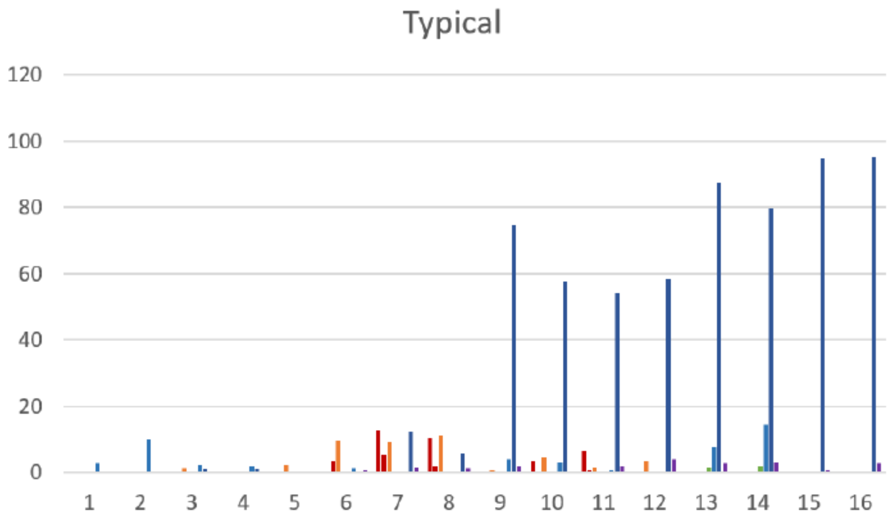


Figure 4.5: Histogram of the color without black, gray, and white

us to draw meaningful conclusions within the game concept art.

## 4.4 Result

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, I 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.

Based on these detailed categorizations and my extensive analysis, I effectively distilled the entirety of my sample dataset into three categories, each category with a distinct set of color characteristics. These typologies, which emerged as the pre-eminent color combinations within the realm of game concept art, are designated as follows: "typical," "balanced," and "monochrome." Through this categorization, I unveiled the essential patterns and intricacies that underlie the fascinating world of color dynamics in the context of my game concept art analysis.

Figure 4.6: The samples of typical color combinations.[9]

Figure 4.7: The samples of monochrome color combinations.[9]

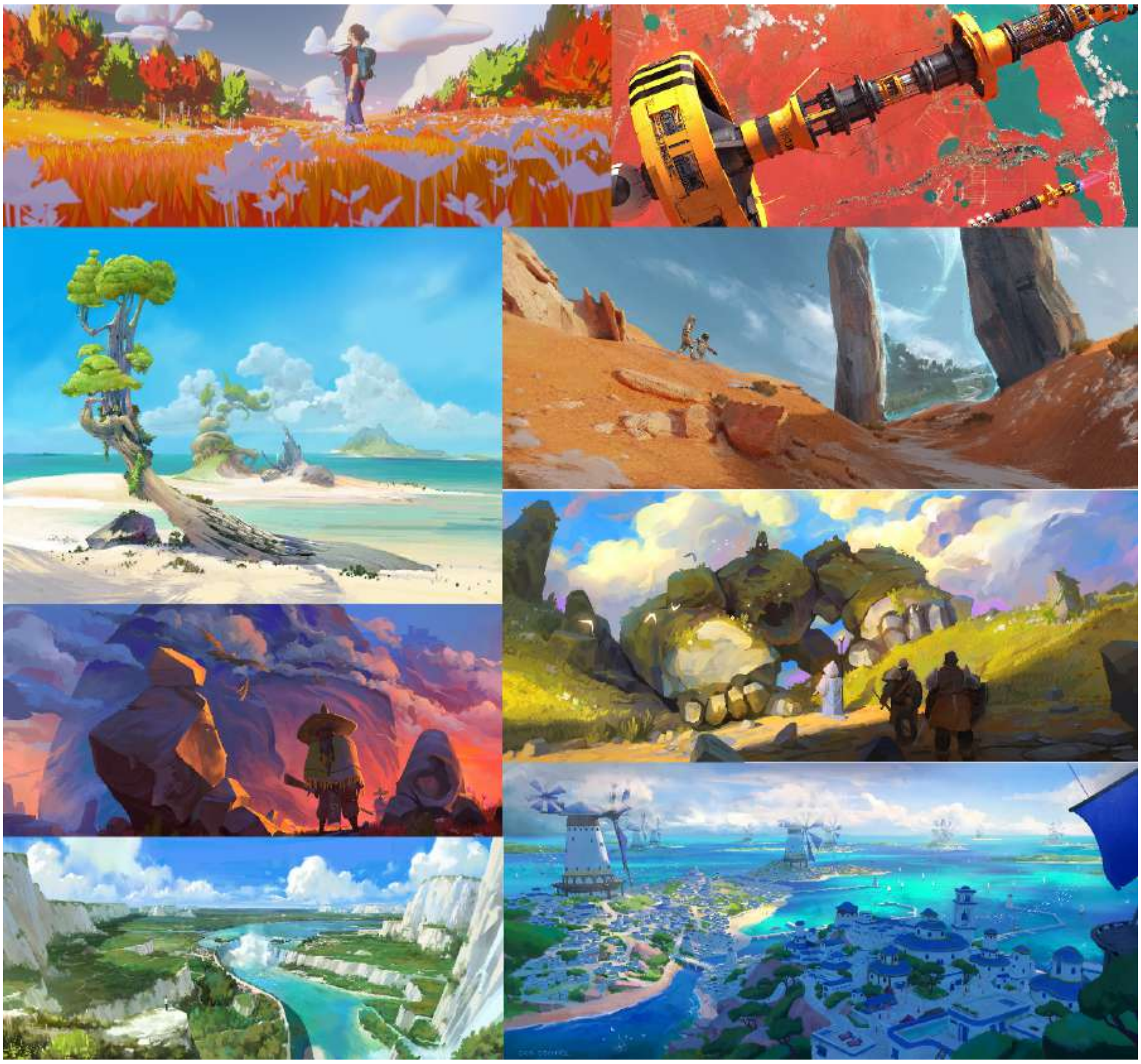

Figure 4.8: The samples of balance color combinations.[9]

### 4.4.1 Typical

The first prominent color combination, identified as the "typical(Figure 4.6)" category, is prevalent in approximately 36.61% of my sample dataset, as shown in Table 4.1. An illustrative example, Figure 4.9, exemplifies this category. What sets this combination apart is the stark contrast it exhibits within the visual center region, where a vibrant interplay of colors is notably evident. In contrast, the non-visual center area is predominantly characterized by a harmonious palette of analogous colors. For instance, in Figure 4.4, I can observe a substantial presence of gray, comprising a significant 51.03% of the image, and blue, accounting for 38.96% of the overall composition; these colors are primarily situated in the non-visual center portion. Remarkably, the visual center region stands out with an abundance of diverse color combinations.

These findings often highlight a noteworthy phenomenon: within the visual center, there are complementary color pairs with lower contrast. 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.

### 4.4.2 Monochrome

The second color combination, monochrome(Figure 4.7 and Figure 4.11), 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 4.12 illustrates the distribution of colors, indicating that black accounted for 55.50%, while white accounted for 18.17%.

Consequently, black and white colors collectively constitute most of the game's concept art. Because of the large proportion of black and white, I created additional tables for this type of sample for color analysis. After removing the proportion of black and white colors, I generated Figure 4.13. Overall, red comprises 14.61% of the entire composition. However, when narrowing my focus to the visual center, the

Figure 4.9: A example of the typical color combination.[10]

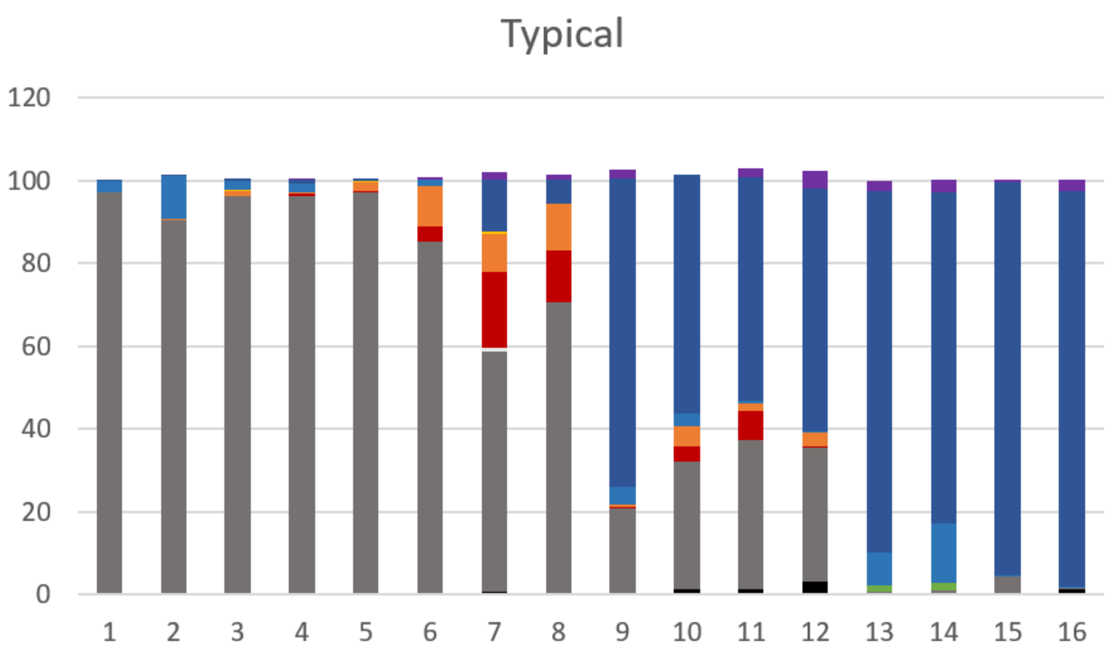


Figure 4.10: The data of typical color combinations.

Figure 4.11: An example of monochrome[11]

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.

### 4.4.3 Balance

The final color combination, referred to as "balanced(Figure 4.8 and Figure 4.14)," accounted for 29.75% of the analyzed sample. This particular combination cannot detect strong color changes in the visual center area in my prior research. Thereby there is no red line to highlight the visual center area. As shown in Figure 4.14, 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 4.15, 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.

### 4.4.4 Correlation

I used an experiment to calculate the positive correlation between color changes and the visual center. Fifty participants were recruited to discern the visual center in each image. To facilitate this task, an interactive application was developed by

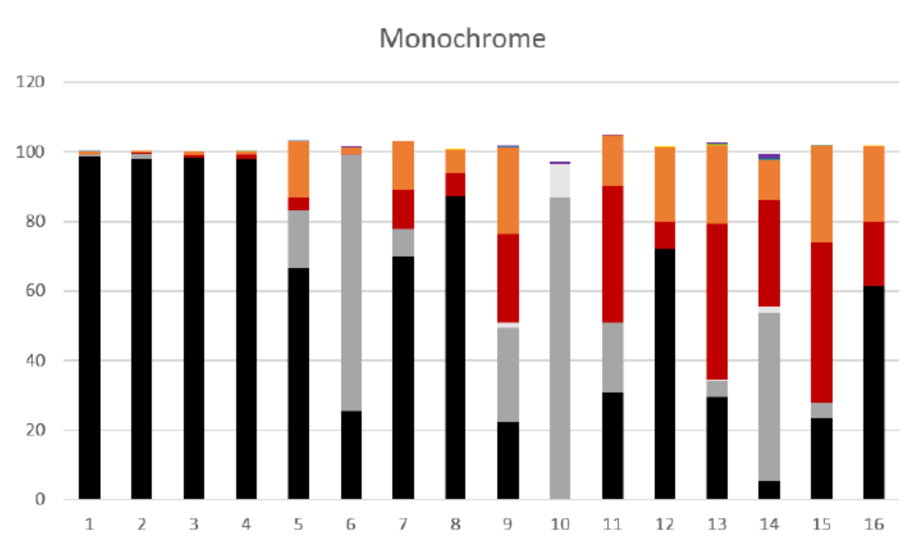


Figure 4.12: The data of monochrome color combination.

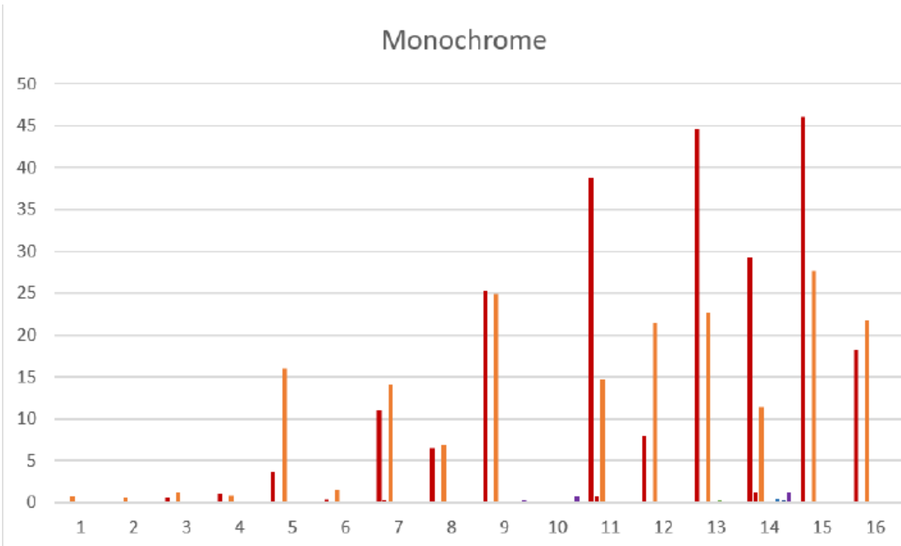


Figure 4.13: The data of monochrome color combination.

Figure 4.14: An example of the balance color combination[12]

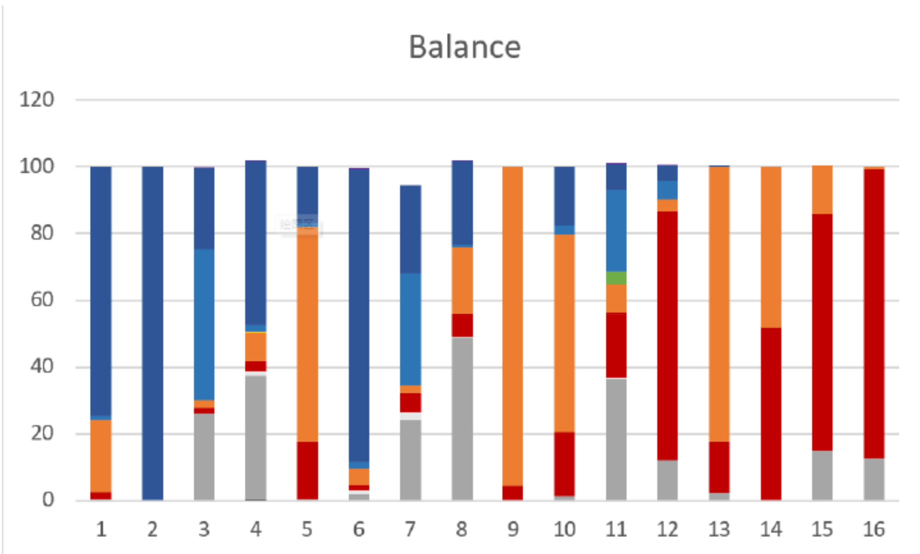


Figure 4.15: The data of balanced color combination


Figure 4.16: I compared the coloring method based on my data with existing coloring methods. The results show that my coloring method shows the visual center better.

us using Python. Participants were able to designate the visual center of each image through a manual clicking screen. Subsequently, I merge all the results. As shown in Figure 16, the regions where the dots exhibit the greatest density serve as the visual center. and I 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.

As shown in Figure 4.16,I try to apply the obtained conclusions to colorization. The left side of the figure is the coloring results of existing studies, and the right side is the coloring results of my data. It can be found that the result on the right is more in line with the expectations of the game concept design drawing. And the visual center is more obvious and clear.

The disadvantage is that in order to highlight the visual center in this process, the contrast of the non-visual center of the picture will be lost, thereby reducing some of the details in the non-visual center.

## 4.5 Discussion

I meticulously analyze a total of 1600 local regions within the industry of game concept art, summarizing the identification of three primary color combinations. Moreover, I have adeptly characterized these combinations, taking into account critical attributes such as proportion, saturation, lightness, and hue. Importantly, I have validated a notable association between color contrast and the visual center, establishing a strong and positive correlation. my result is more suitable for colorization in game concept art

However, it is crucial to acknowledge several limitations within the scope of this study. Analyzing colorful, cartoon-style samples presents inherent challenges, as their complexity and vividness can potentially hinder the precision of my detection. Additionally, the segmentation of crucial areas during the image segmentation process could potentially introduce misdetection in my analysis results.

Moving forward, my research path will be separated into two pivotal areas of exploration. Firstly, I am committed to refining and optimizing the outcomes of my existing experiments. I am diligently working to optimize the range of color values, thus augmenting the practical applicability of my findings, especially within the domains of painting instruction and AI-based painting systems. Secondly, my research focus will expand to encompass what influences viewers' attention in the industry of digital artwork. For instance, I intend to delve into the impact of specific objects or diverse compositional arrangements in effectively directing and engaging viewers' gaze toward the visual center—a dimension that holds immense significance in the world of visual aesthetics and design.

## 4.6 Chapter Conclusions

This chapter outlines a comprehensive research methodology centered on the analysis of color patterns within game concept art, approached from an artistic standpoint. This method entails several pivotal steps and considerations.

The initial step involves image segmentation, a process used to differentiate between the visual center and non-visual center regions within the game concept art. Here, a 4x4 grid segmentation approach is chosen for its efficiency in selecting these crucial regions.

In the subsequent step, the study classifies color intervals based on the HSV (hue, saturation, value) values, a deliberate choice due to its alignment with traditional color mixing methods. The research strives to meticulously explore the proportions of each color interval within individual local regions, aiming to reveal discernible patterns in color usage. The data gathered through this process is then meticulously compiled into a table, paving the way for insightful analyses to draw definitive conclusions about fundamental color combination patterns.

The subsequent data analysis entails converting color values into distinct color labels grounded in the HSV range, enumerating the pixel count within each color label, and subsequently crafting a comprehensive histogram. This analytical approach serves as a valuable tool for individual local regions.

This chapter grapples with a substantial data set, comprising 100 instances of game concept art, each meticulously segmented into 16 local regions. The intensive analysis of a total of 1600 local regions uncovers distinctive and noteworthy patterns in color combinations in game concept art.

Ultimately, this chapter separated samples into three discernible typologies of color combinations: "typical," "balanced," and "monochrome."

# Chapter 5

# General Discussion

In the previous sections, I analyzed the patterns of color usage in the conceptual design drawings of the game. I divided the study into two parts. The first one is to process the image to analyze the visual center of the game concept design diagram, and the second part is to analyze the color of the visual center and non-visual center respectively, and summarize the law.

My algorithm design idea is based on the idea of the game concept designer when designing the screen. Usually when the game concept designer designs the artworks and game concept art. The area in the visual center will use stronger color contrast and richer color variations. But in the non-visual center area, the contrast will be weakened. The sky, for example, is mostly simply blue and white in the non-visual center. In the first section, I refer to the bags of color model and cut the image. Then for each local region, a hash algorithm is used to create color labels. For single color local region is classified and segmented. Thus similar labels mean that the color combinations are single and similar, which means non-visually centered regions. If the combination of colors is rich and unique in the image, it means that the region is the visual center.

I compare this research method with the results of previous algorithms for similar studies of saliency. It can be seen that the results obtained are superior to the saliency algorithm. This is because the saliency algorithm focuses more on object recognition or analyzing pixel changes for the whole image. The novelty of my study is the concept of visual center, which is more commonly used in game conceptual designs. The authors believe that the method mentioned in the first part is only suitable for detecting the visual center of game concept art.

At the same time, during the experiment, I also found the problems of my method. In game concept art, it is undeniable that game concept designers design the visual center in many ways. In addition to color and composition, the use of objects is also

Figure 5.1: For example, in the sample shown in the picture, if the character is cut by segmentation, there will be a certain probability that the visual center cannot be detected.

a traditional method of designing visual centers. However, my cutting method may cut right into the subject matter resulting in no way to identify the area of the visual center. as shown in Figure 6.1, I can't detect the visual center, if I cut the picture through the character in the image.

In the second part of the study, I began my analysis of color based on the first part of the study. First, I established the color space, and in the choice of color space, I chose the HSV color space which is closer to human cognitive colors. In my study of traditional painting is the cognitive approach using the HSV color space. On this basis, I created an approximate interval for each color. Then I counted the proportion of pixels occupied by each color in each local region. After analyzing one hundred charts, I summarized the pattern of color usage. I summarized the patterns into three main categories.

The conclusions of these color combinations can be applied to the teaching of traditional painting and colorization, and can also lay the foundation for my future research. After that, I would like to try to combine colorization with my current research in detail. Further, enhances the results of colorization.

But at the same time, the second part also has certain limitations. Painting is different from math or physics, his laws and results often have no critical correct answers. To put it another way, common conclusions often fail to hold artistic value. Art is often in pursuit of the artist's unique expression and what he or she expresses. Universal conclusions are more in favor of production tools. My conclusions are for the data analysis to summarize the law. That is to say, he composites contemporary popular aesthetics, but he finds it difficult to form stylized content.

In the end, the authors believe that these studies in the direction of game concept design are a beginning, and hope that future research can be based on these contents to further expand the direction of game art-related research. It is hoped that future research can use these contents as the basis to further expand the research related to the direction of game art, and provide more interesting and practical conclusions for game art and even art.

# Chapter 6

# Conclusions

In my study, I started by creating a tool for focusing on visuals inspired by game concept art. I wanted to capture the artistic essence by blending painting principles into an algorithm. my goal was to break new ground in game concept art and open doors for game design and painting. my research is divided into two stages. The first stage is the detection of the visual center, and the second stage is the analysis of color combinations.

as shown in Figure 6.1, compared with other saliency methods, my method far exceeds existing methods in accuracy. Compared with other colorization methods, my colorization method can be better applied in game concept art.

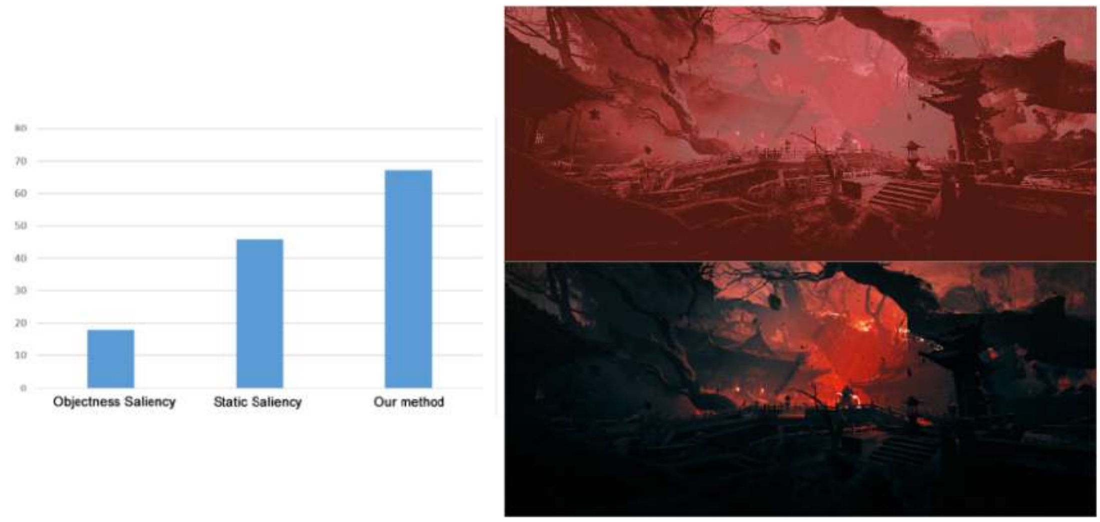


Figure 6.1: Results compare with existing research

Yet, I also faced some limitations. How I split the artwork affected my analysis—too much or too little segmentation led to mistakes. Game concept art includes various elements like characters, creatures, machinery, and monsters, each crucial to the design. However, including them wrongly during segmentation could mess up the analysis. Dark and minimalist art styles also made it tough for my method to detect details.

Moving forward, I plan to work on two main things. First, we'll improve the visual attention tool to handle segmentation issues better. Then, we're diving into studying how colors are used and how they impact where people look.

I dug deep into 1600 local regions in game concept art, finding three main color combos and studying their proportions, brightness, and more. my work confirmed that more color contrast usually aligns with where people look.

But, as always, there were challenges. Analyzing colorful, cartoon-like samples was tricky, and my method might accidentally chop out important parts of the images.

Looking ahead, we're aiming to refine my experiments' results and make them more useful, especially in painting and AI-based systems. Then, we'll broaden my research to understand how different factors in digital artwork direct people's attention. This involves studying specific objects and layouts to grasp the connection between art, psychology, and tech better.

# Publications

## Journals


[1] San, Tiancheng, Yoshihisa Kanematsu, and Koji Mikami. "An Analysis of Visual Interest Detection in 2D Game Concept Art." Journal for Geometry and Graphics 27.1 (2023): 69-79.

[2] San, Tiancheng, Yoshihisa Kanematsu, and Koji Mikami. "Algorithmic Analysis of Color Combinations Principle in Game Concept Art " The Journal of the Society for Art and Science, Vol. 99, No. 9, pp. 99:1-99:3 (2099)


## Conferences


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[4] San, Tiancheng, Koji Mikami, and Yoshihisa Kanematsu."Visual center and non-visual center of the color combination principle" ADADA+CUMULUS, 2022.

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