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JAPAN ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY

Japan Advanced Institute of Science and Technology

A Research on Chinese Traditional Color Harmony Digitization Inheritance Method and Application

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Japan Advanced Institute of Science and Technology

Doctoral Dissertation

A Research on Chinese Traditional Color Harmony Digitization Inheritance Method and Application

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Graduate School of Advanced Science and Technology

Japan Advanced Institute of Science and Technology

Knowledge Science

March 2022

Written on the Wall at West Forest Temple

It’s a range viewed in face and peaks viewed from the side,

Assuming different shapes viewed from far and wide.

Of Mountain Lu, we cannot make out the true face,

For we are lost in the heart of the very place.

Su Shi

Translate by Xv Yuanchong

Different Views, Make Difference.

ABSTRACT

Chinese Traditional Color Culture（CTCC）has a history of thousands of years. The Chinese traditional color system is complex and huge, it had derived the world-famous Dunhuang Mogao Grottoes murals, tri-color glazed pottery of Tang dynasty, blue and white porcelain, Tibetan Thangkas, colorful folk crafts, etc. It has great influence and value in the field of art throughout China and the world. Traditional color culture is an indispensable part and important social element in the development and change of every social stage. The changes in various social stages have inherited and developed the traditional color culture of the previous society. But the CTCC as intangible cultural heritage is too complex to understand and usage in the real project, it required lots of professional knowledge that is an uneasy thing for most people. To be better make people comprehend CTCC, and make it easy to use. Accordingly, to inherit the CTCC and CTCH, it should be studied with scientific theories and principles, it needs to cater to the aesthetic and mentality requirements of society and people, it needs to meet the need of development of age and era, and using it should be practice with new tech approach.

This study intends to make art and aesthetics with a scientific approach. The purpose of this research is to inherit Chinese traditional color culture. The objective of this dissertation is to inherit Chinese traditional color harmony (CTCH) with digitization manner. This dissertation aims to present the method of digitization of inheritance and application for the CTCH that contains conservation, improvement, development (CID) which can be a circulation system. Strikingly, the contents of this research are based on theory and principle from the tradition which is the root of the culture for future innovation.

The CTCC is an intangible cultural heritage, how to protect and conserve it that is a hard problem. Digital processing technology is an important means of information preservation. The first contribution is the proposed extraction approach with a digitization color scheme for Chinese traditional artwork. The research work takes the Chinese traditional color scheme (CTCS) as the research objective, combined with color science, to build up the method to extract and record CTCH via the dataset. Based on the CTCS results and evaluation from the method of this work, are more suitable for cognition degree and aesthetic of participations compare with others` methods.

The CTCH has a history of thousands of years, it has strong historical characteristics, and it needs to be integrated into modern society in a new way. The second contribution is the proposed improvement approach that is based upon the deep learning method for the CTCH, with the common aesthetic preference of contemporary people. In the viewpoint of research that the CTCC should meet the needs of the development of the times, cognitive, and aesthetic characteristics of contemporary people. To achieve the goal, research work had built up the model and architecture which were used for the generation and optimization of CTCH had been proposed.

As tacit knowledge, CTCC and CTCH are hard to comprehend for most people, it needs to be transformed through a process that can offer an easy way for people to understand. The third contribution is proposed the development method with two kinds of interactive system which is included approach of web color matching application and VR learning. First, the website interactive color matching system had been proposed which is the case of high-speed railway. Second, the VR interactive learning system had been proposed. Via this part, the CTCH color scheme application is based upon the CTCH dataset, aesthetic perceptual factors, and knowledge model had been explored that, how to use the CTCH in practice way with applications.

Finally, based upon four parts of the work, a novel inheritance method named the CID systematic method had been constructed. The method is based on the combination of theoretical methods and practical methods. Through each part of the evaluation which testifies the CID approach is successfully achieved the research aim set in begin of this work. This research is both deepening Chinese traditional aesthetic theory and expansion of the practice and application approach for CTCH. More importantly, the CID method is not only suitable for CTCC and CTCH but also can provide a reference for related color culture research. Nevertheless, inheriting CTCC and CTCH is the long way demand to go further and deeper, it is also required supplement and enrichment by related disciplines and fields. It is hoped that more and more cultures and civilizations in the world will be conserved and usage that no matter how small it is, they are all significant cultural heritages and important knowledge of mankind, that are the source of innovation and foundation for future.

Keywords: Inheritance Method; Aesthetic Renew; Color Scheme Harmony; Color Scheme generation and optimization; Interaction System;

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Figure 5-1 Harmonious Collocation form (https://paletton.com/).

LIST OF THE CHART

LIST OF ABBREVIATIONS

CID: Conservation, Improvement, and Development.

CTCC: Chinese Traditional Color Culture.

CTCH: Chinese Traditional Color Harmony.

CTCS: Chinese Traditional Color Scheme.

CTAW: Chinese Traditional Art-Work.

CNKI: China National Knowledge Infrastructure.

CL: Colour_Lover website.

GB/T 31430-2015: Names and colorimetric characteristics of traditional colors in China.

GB/T 3977-2008: Specification of colors.

GB/T 7921-2008: Uniform color space and color difference formula.

GAN: Generative Adversarial Networks.

HSR: China's high-speed rail.

KE: Kansei Engineering.

HCI: Human-computer Interaction.

MRQ: Major Research Question.

NIMA: Neural Image Assessment.

SRQ: Subsidiary Research Questions.

VR: Virtual Reality.

WOS: Web of Science.

WGAN-GP: Wasserstein GAN Gradient Penalty.

CHAPTER 1 Introduction

1.1 Background

1.2 Complexity topic

1.3 Research questions

1.4 Objective and Aim

1.5 Method Overview

1.6 Novelty

1.7 Contributions for Knowledge Science

1.8 Outline and structure

Overview

Chapter 1, describes the general content of the dissertation. It begins by reviewing the historical background and internal relationship of CTCC and CTCH and declaring its development in the context of the timeline. Thereafter, it expounds on the phenomena and summarized problems existing in the contemporary CTCC, and obtains the CTCC and CTCH questions that this dissertation will be solved. Subsequently, illustrate the macroscopical level method for this study. then, a brief description of the innovation of the research. Finally, the chapter ends by reviewing each chapter of the outline structure of the dissertation.

1.1 Background

1.1.1 Historical Review of Chinese Traditional Color Harmony

The power of intangible cultural heritage is noble, it is closely connected with natural culture, it is deeply combined with national root culture, and it protects the seeds of human culture. The birth of the list of intangible cultural heritage around the world shows that mankind has promoted the significance and value of national culture to the human level (Xiang, 2018). It indicates that mankind has realized that intangible cultural heritage as a living cultural heritage is the knowledge source of human cultural innovation and the importance of cultural identity and sense of history. The history timeline is shown in Figure 1-1.

As an intangible cultural heritage, CTCC still shines brightly after wind and rain. CTCC has a history of thousands of years which can be date back as early as 1600 before the Common Era (BC),(T.-R. Lee, 2012). Chinese traditional color harmony (CTCH) is an important part of Chinese traditional color culture (CTCC) which is the formation and theoretical basis. And the Five-Elements-Theory is one of the significant concepts in CTCH theory. It is a cultural model of Chinese civilization in the aesthetic concept (X. Zhang et al., 2012). Nowadays, CTCC and CTCH still have a far-reaching impact on contemporary CTCC and Asian color culture (Ishai et al., 2007).

Since the official etiquette system was formed in the Zhou Dynasty (1046 AC-256 BC), the Chinese traditional concept of color harmony and the color system has been gradually formed, but it is the prototype conception. The principle of the CTCH is derived from the philosophy of Yin-Yang and Five-elements aesthetic theories which is the foundation aesthetic theory of CTCC.

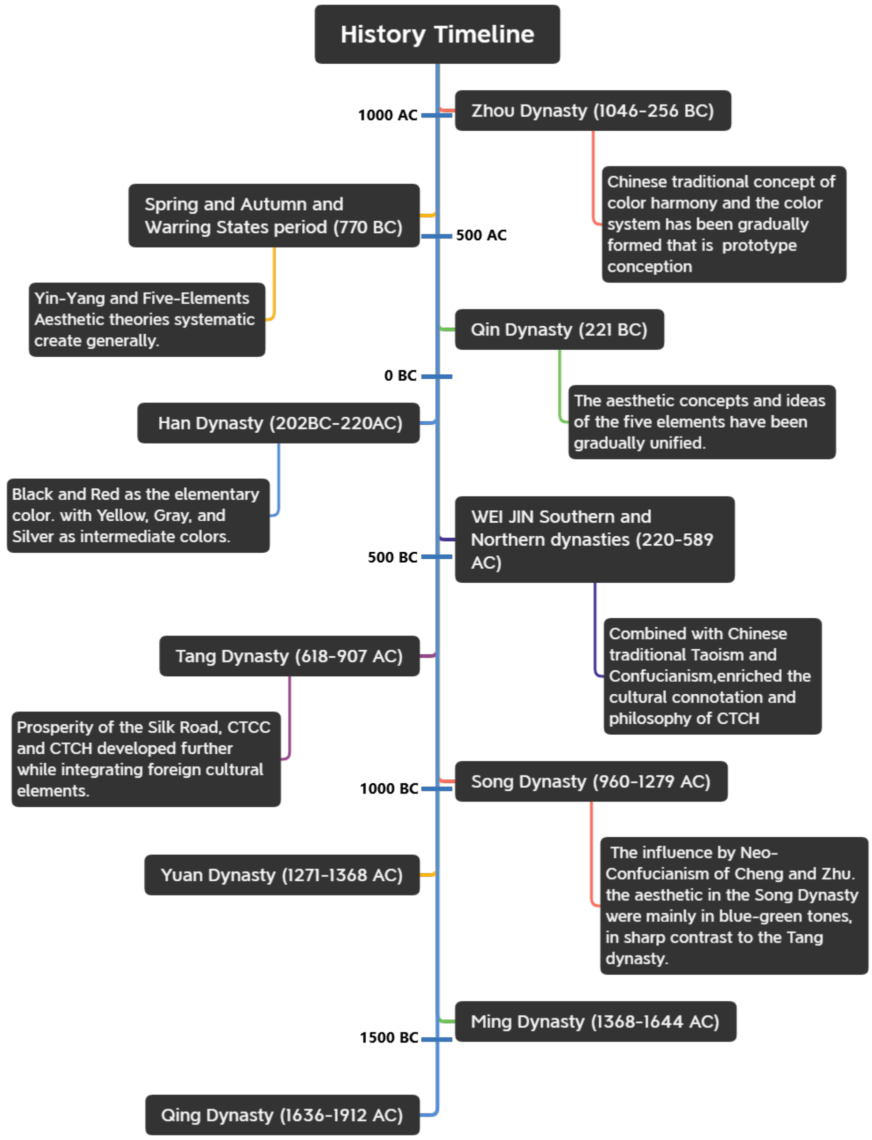


Fig. 1-1 History Timeline

In the Spring and Autumn and Warring States period (770 BC), the color culture of Confucianism and Taoism formed the embryonic form of people's understanding of color, and the theory of Yin-Yang and Five-elements was also born in this period and became the traditional philosophical basis of the aesthetics of the Five-elements, The Yin-Yang, and the Five Elements as shown in Figure 1-2. With the rise of the Yin-Yang and Five- elements theory, CTCC gradually presents a diversified development trend, changing from a simple color decoration purpose to a functional and symbolic purpose. The Chinese ancients believed that all things in the world were created by five basic elements, namely, the water, the fire, the wood, the metal, and the earth. The Chinese ancients think that the Five-elements were the five kinds of foundation that produced the origin of all-natural things.

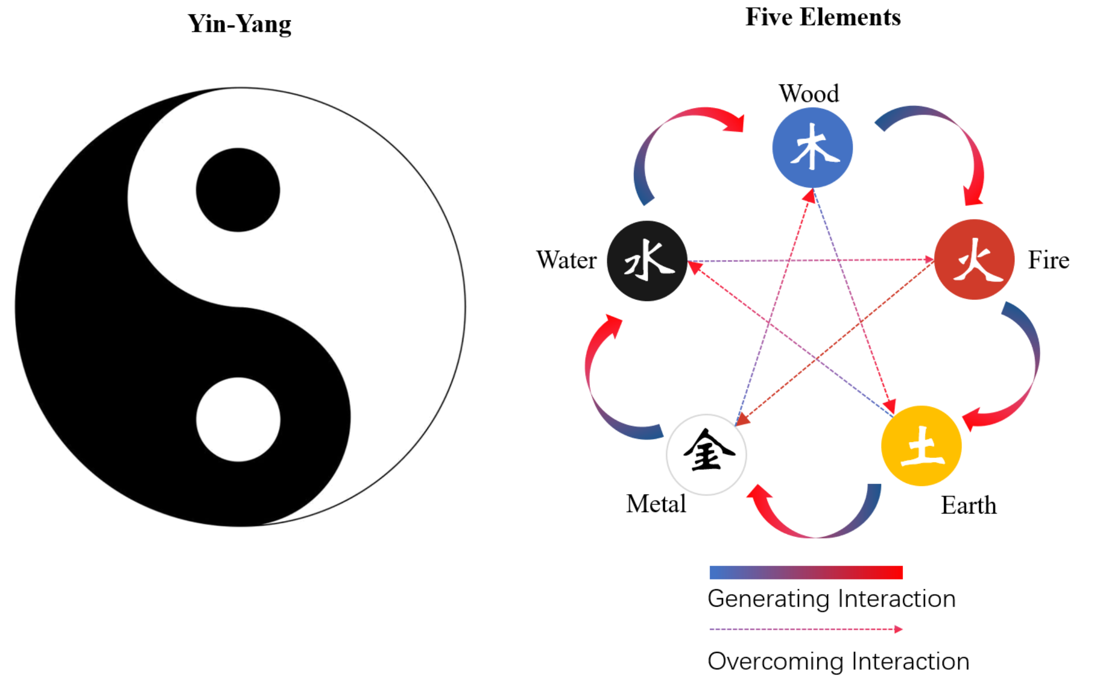


Fig 1-2 Yin-Yang and Five Elements

Philosophy relationship between the color and the law of natural movement of heaven is gradually established, the theory of Five-colors is formed. In the conception of the Five-element color concept, the Five-colors refer to the five kinds of categories, which are usually expressed as blue, red, yellow, white, and black, those category called (M. S. Lee et al., 2012). In traditionally five-element aesthetics, the intermediate color is created by blending other colors through various levels of the black color and the white color, even the black and the white itself can be subdivided in the various level that involved different aesthetic and philosophical meanings (D. Hu, 1995). To achieve the change of color brightness, purity, saturation, and then produce different approaches to the color scheme.

BC 221, Emperor Qin unified China and founded the Qin Dynasty. During this period, CTCC iconicity was further extended, following the rule that the ancient people's observation of things and the formation of the image of things give the color scheme a deeper meaning. The symbol is expressed by the image formed by the color combination, which is like the change of seasons and the definition of orientation. Spring is Qing-Yang color, the direction is mainly east, the patron saint is Qing-Long (God of the Dragon). Summer for Zhu-Ming color, the direction of the main south, a patron saint is Zhu-Que (God of the Phoenix); Autumn is plain white-autumn color, the direction of the main west, the patron saint is Bai-Hu (God of the Tiger); Winter for Xuan-Dong color, the direction of the north, the patron saint is Xuan-Wu (God of the Tortoise) (L. Chen et al., 2014), the Patron Saints are shown in Figure1-3. Among them, yellow is respected as the orthodox color, regarded as the lord of color, on top of all colors, and represents the color of the earth, and gradually evolved into a symbol of royal power. Some of these cultural phenomena are continued in contemporary Japan. This conception of CTCH which is the combination of the Yin-Yang theory and Five-elements has deeply influenced CTCC and Asian color culture (Ishai et al., 2007).

Fig. 1-3 Patron Saint

During the Han Dynasty (202 BC-220 AC), color harmony of five-element aesthetics had been built up by the color combination of elementary color and intermediate color on aesthetic style. The color scheme of the Han dynasty mainly followed the CHU culture which is one country of Spring and Autumn and Warring States period (770-221 BC), and the specific color use was Black and Red as the elementary color. with yellow, gray, and silver as intermediate colors. The overall color effect is chromatic and bright. At the same time, arise with the prosperity of Confucianism, Confucianism integrated and applied the concept of "harmony" within colors, forming the early concept of CTCH, and the CTCH system took shape (Lin, 2014).

Thereafter, during the WEI JIN Southern and Northern dynasties (220-589 AC), Buddhism was introduced into China and flourished in the official and folk, and combined with Chinese traditional Taoism and Confucianism, enriched the cultural connotation and philosophy of CTCH. CTCH began to run through all fields of Chinese color aesthetic consciousness gradually, from imperial etiquette to folk customs, and the development during this period had a far-reaching impact on Chinese traditional color culture (C. Zhang, 2017).

During the Tang Dynasty (618-907 AC), with the prosperity of the Silk Road, CTCC and CTCH developed further while integrating foreign cultural elements. Due to the introduction of exotic and western novel color matching methods, the hue and tone in CTCS during this period changed from simple and gloomy to bright and gorgeous, full of strong exotic customs. Such as, the Tri-colored glazed pottery and the five colors of the Tang Dynasty are brilliant and bright. In Dun-Huang grottoes frescoes, the elementary color is mainly red and brown, with cyan and black to add yellow, forming a richer color combination and visual effect, and contains religious meaning (Abrams, 2021).

In the Song Dynasty (960-1279 AC), due to historical reasons, the ideology and culture were far inferior to that of the Tang Dynasty. With the decline of national strength and the influence of Neo-Confucianism of Cheng and Zhu. the secluded and refined taste of aesthetic was bred in the expression of harmonious colors. Accordingly, the murals in the Song Dynasty were mainly in blue-green tones, in sharp contrast to the Tang dynasty.

Unfortunately, during modern times with the introduction of western learning and the changes in modern Chinese history, CTCC and CTCH have gradually disappeared in the classics, to inherit CTCC is the problem that needs to be solved. the application concept of CTCC is scattered and unorganized and gradually disappears in the old paper inscriptions (Yunzhi, 2007). In addition, due to the restriction of historical conditions, the limitation of the development of the scientific system, and the abstractness of philosophical and aesthetic concepts, CTCC and CTCH inherit the essential problems (Kim, 1982).

1.1.2 Global Review of Digitization Culture Heritage

The concept of heritage covers the natural, cultural, and industrial domains and is a comprehensive account of historical development (UNESCO, 2021). Cultural heritage refers to historical sites and expressions that have lasting value in contemporary society (UNESCO, 1989). As human knowledge, cultural heritage has been transformed from a simple social material heritage into a collective cultural memory constructed by the state (Type & Paper, 2021). Digital heritage, which is technically intangible, consists of human knowledge or expressive resources (UNESCO, 2018).

World Summit on the Information Society (WSIS) conference proposed that the future information society should utilize and protect cultural heritage in all appropriate ways, including digitization. Digital heritage focuses on material and intangible cultural heritage items and their conservation, education, and research (Owens, 2013). Digital cultural heritage refers to the various forms of expression of experiences designed to enrich, complement, or preserve heritage sites or objects of historical and cultural value as a result of the effective use of digital computer technology (UNESCO,2021). Such as text, images, sound, graphics, software, virtual objects, etc. (Communication, 2021).

The digitization of cultural heritage is an important measure of cultural heritage. In 2002, the American Library and Information Resources Committee launched a survey of the North American Digital Cultural Heritage Initiative. It helps to strengthen the coordinated strategy formulation of digital cultural heritage strategy and its by-products (Background et al., 2003). European member States have carried out a wide range of activities in the field of digital cultural heritage to establish a data infrastructure dedicated to cultural heritage research to achieve a road map for the preservation of digital cultural content (Fresa, 2013). A survey describes the data of more than 1,000 libraries, archives, and related cultural institutions in Europe, which records the current status of digitization of cultural heritage in Europe (Stroeker & Vogels, 2014).

Since the 1960s, the emergence and development of computer science and computer graphics technology, has provided a new way for the digital protection and dissemination of cultural heritage (Münster et al., 2019). Since the 1990s, people have used new technology to create a large number of digital content that includes digital images, digital video, digital sound, digital art, and so on. The purpose of these digital materials is not only to preserve the content digitally, but also to allow and expand access to it for researchers, students, and citizens. The significant advantage of the digitization of cultural heritage is that data materials converted into data form can provide real-time storage, processing, sharing, and transmission of information (Masciotta et al., 2021). In addition, the content of digital culture is reusable and easy to reuse (Fresa, 2013).

At the same time, with the popularization of the information model, graphics, 3D visualization, and virtual reality, the research ways of digitization of cultural heritage have been promoted. Computer science and the use of computer programs to record cultural heritage, computer visualization technology has become an indispensable tool in the field of digital cultural heritage (Evens & Hauttekeete, 2011). It provides a digital approach to cultural heritage and provides a description and explanation for the combination of reality and virtual. Digital information is fundamentally reshaping the production, dissemination, use, and reuse of information and knowledge in society. The preservation of digital cultural storage ensures the availability of cultural heritage (Stroeker & Vogels, 2014).

Computer visualization can be used as a method and means to study and communicate cultural heritage. It advocates the establishment of a set of scientific methods, and virtual materials need to have a set of metadata and interactive metadata to facilitate experts in different fields to verify and evaluate them (Münster et al., 2019). In addition, the research on the digitization of cultural heritage mainly focuses on three aspects, namely, collection, preservation, and development. At the collection level, focus on filing, recording, inventory compilation.

Digitally transform the cultural heritage and record the physical information of the object comprehensively (Hall et al., 2012). The research at the protection level mainly involves metadata, ontology, semantics, and preservation media. With the acceleration of the digitization of cultural heritage resources, digital resources gradually form a large-scale development trend. The project is an excellent example of its practical example in the digitization of cultural heritage and metadata standardization, leading the digital transformation of cultural heritage and promoting cross-border cooperation and digital standard-setting activities in Europe (Fresa, 2013). This digital conservation operation digitally stores monuments and sites. To ensure that content in the form of data is saved and transmitted to future generations.

In recent years, with the improvement of the performance of computer hardware and the popularization of application, the digitization of cultural heritage, 3D model reconstruction, and interactive application are on the rise. It has given birth to new concepts of digital cultural heritage, such as digital heritage, digital archaeology, virtual heritage, a virtual museum, and so on. And gradually formed the research direction of cultural heritage informatics. In 1990, Paul Reilly first put forward the concept of virtual archaeology, which promoted the transformation of the thinking model of digital cultural heritage. The research work of Stanco Filippo et al. introduced the application of digital imaging of cultural heritage based on computer graphics, analysis, restoration, reconstruction, and digital image processing of ancient works of art (Stanco et al., 2018). Leonardo Gomes, who has made an in-depth exploration in the field of 3D reconstruction, puts forward research on the method of 3D reconstruction for the digital protection of cultural heritage (Gomes et al., 2014).

The Inclusive Culture Heritage in Europe through 3D Semantic Modelling (INCEPTION) project was launched in Europe in June 2015, which is based on web-based solutions and applications, realizes efficient 3D digitization methods, and enriches post-processing tools for semantic modeling. Through the identification of the semantic ontology of cultural heritage and the data structure of information catalog, the semantic attributes and hierarchies are combined to realize the data integration of a three-dimensional digital geometric model, and then to achieve the information management of cultural heritage.

1.2 Complexity Questions

1.2.1 Decentralization and Fragmentation

a. Historical dimension.

The historical dimension of CTCC spans a great chasm from each stage, and there are many categories in each period. This also leads to the fact that relevant protectors and researchers only study them from their respective disciplines, and it is difficult to form a comprehensive system. In addition, after the hundreds of years or even millennia of baptism, many of the material matter that can be collected today are no longer in their prime. Equally, due to the stability factors such as plants and minerals used in the production of pigments, the preservation and protection of pigment of matters become more and more difficult with the passage of time and the problems such as oxidation, color fading, and damage of pigment of matters (Song, 2019), such as shown in Figure 1-4.

Fig 1-4 Problems of Oxidation, Color Fading, and Damaged.

b. Literature and Context.

The limitation of the literature describing CTCC and CTCH is expressed in ancient Chinese prose, and the relevant literature is mixed with traditional philosophical concepts which are hard for non-professional background researchers (Hou, 2004). The names of colors are named with moral meaning or image in a specific historical period, which is difficult to combine with specific pigment substances and difficult to interpret and understand for the general population and the general public (Louise, 2015). This is also one of the limiting factors that most Chinese traditional colors and CTCH are difficult to reproduce.

1.2.2 Lag and Backwardness

a. chromaticity dimension.

The existing Chinese traditional color system is finitude, for example, 625 colors are involved in the 1957 chromatogram, which is the earliest available literature on the expression of Chinese traditional color in modern times (http://zhongguose.com). The traditional Color of

China, published by Japan in 1986, contains 320 colors (https://htmlcss.jp/color/china.html). The DIC traditional Color of China contains 320 colors.

(https://www.colortell.com/colorbook/?callbook=s).

The Chinese national Color system, published in 1995, contains 1338 colors. The Chinese national standard named "Chinese traditional Color names and chromaticity characteristics", published in 2015 contains 164 colors. Most of these projects try to quantify the accuracy of Chinese traditional color, but up to now, there is still not a relatively perfect color matching system of Chinese traditional color (Zeng, 2014). The reason is that the Chinese traditional color culture is numerous and complicated, the span of the artistic style contained in the historical stage is intricacy and complexity, and it is difficult to divide the artistic style characteristics of different periods. In addition, massive historical matters need to be recovered and restored, and the main reason is that none of them can be used and referred to as the general standard of traditional Chinese aesthetics and can provide shared and constantly updated quantitative data. Compared with the optics-based color research in the West, it lacks systematization and professionalism (Kim, 1982)

b. Normative dimension.

Human cognition and practice of color have a history of tens of thousands of years. However, the history of color that can be called science is a short time, especially the history of the study of color harmony, harmony format, and formation from the scientific point of view. Many country`s chromatics has formed the system of color theory and color application, such as America, Pantone, and Munsell color system (Y. Wang, 2017). Japan, Practical Color Coordinate System (PCCS) (Hsiao et al., 2017). Swedish. Natural Color system (NCS), etc. (Hård & Sivik, 2001).

The research on color discipline in contemporary Chinese academic circles still tends to be fragmented which is lack of comprehensive carding and precipitation, and Chinese chromatism has not yet taken the full attention of CTCC and CTCH in practice with theory (Zeng, 2014). In the application, it has not formed its mature color system and application methods (Kim, 1982). Additionally, the work on CTCC is majority limited to theory research, lack of practical application research, more important is how to integrate all research results and constantly improve and update the systematic results. Although in 2015, China published the latest national color standard, called ***Names and colorimetric characteristics of traditional***

colors in China (GB/T 31430-2015), the Chinese traditional colors standard only involved 164 colors in it, which is far more enough for CTCH study, but relate work must follow this standard.

1.2.3 Stagnation and Conformism

Due to the long historical development and cultural accumulation, Chinese people have formed a relatively fixed aesthetic tendency and aesthetic habits, and it also shows a relatively fixed program in the use of color. Red is the respect and admiration color in Chinese culture, symbolizing auspiciousness, joy, progress, success, smoothness, beauty, etc. White symbolizes death, bad omen, plain apparel, plain crown, and so on. Black is a solemn hue. On the one hand, it symbolizes seriousness and justice; on the other hand, it symbolizes insidiousness, bitterness, and terror. This phenomenon began in the Zhou Dynasty, with the Qin Dynasty and Han Dynasty centralized folk began to gradually continue and transmit the use of this color culture.

The aesthetic habit of CTCC has been deeply rooted in the hearts of the people (Du & Wang, 2019). Although the variety of colors has been continuously enriched for thousands of years, the psychological structure of national culture is relatively stable. Under the influence of past times and social and cultural background, CTCC and CTCH have corresponding stability and independence. As the proverb says, every coin has two sides, and CTCC and CTCH is not the exception, is has both advantage and disadvantage. This also leads to the problem of CTCC and CTCH curing. In addition, due to the education of traditional color culture, spread, popularize is far-more enough, and CTCC and CTCH knowledge is only limited in specific areas of the researchers and people. That leads to the masses using CTCC and CTCH with mistakes or misuse.

1.3 Research Questions

To the summary the phenomenon above, and to solve and answer it this dissertation involved one (MRQ) and three (SRQ) as follows:

MRQ: How to inherit and apply CTCC and CTCH with digital manners?

SRQ 1: How to establish the Digital Features of CTCH?

SRQ 2: How to make CTCC and CTCH cater to the aesthetic of contemporary humans?

SRQ 3: How to utilize CTCC and CTCH with reality and a practical approach that can make people use it and comprehend it?

1.4 Definition, Motivation, Objective, and Aim

1.4.1 The Definition of Color Harmony in Chinese

In Chinese, harmony has two characters, and its meaning is divided into two levels. 1 "调 (TIAO)" means adjustment, conditioning, settling, arrangement, collocation, combination, etc. 2. "和 (HE)" The Harmony, peace, harmony, order, propriety, etc. Chinese Traditional color harmony is influenced by the philosophy of "harmony between man and nature", and rushes up the idea of harmony between humans and nature.

1.4.2 The Definition of Color Harmony in Modern

Color harmony refers to two or more colors, orderly, coordinated, and harmonious organization together, can make people feel happy, happy, satisfying color collocation. The theory of color harmony is the knowledge to explore the essence of beauty through the tonality and relationship of colors. Colors seen together to produce a pleasing affective response are said to be in harmony (Nayatani & Sobagaki, 2002) Color harmony is the semantic and aesthetic aspects of color, which is the phenomena that give color the psychological power (Ou & Luo, 2006).

1.4.3 The Definition and Motivation of Research

In the view of this dissertation, the meaning of inheritance is the process of accumulation and re-creation for knowledge. Humans are namely human because they create and accumulate knowledge while maintaining their survival and linebreeding. Generation after generation of human beings create knowledge that belongs to their time and period, some of the knowledge which is recorded in literature, preserved in practice, or taught in words, and passed on to the next generation, opening the wisdom of the next generation. Enlighten the creation and production of knowledge. The creation and production of knowledge are continuously continued and passed on from generation to generation. That makes the various culture can inherit with the process.

1.4.4 The Objective and Aim

As an intangible cultural heritage, CTCC and CTCH still shine brightly after wind and rain. CTCC has a history of thousands of years which can be date back as early as 1600 before the Common Era. Part of CTCH begin a long time ago, part of it had missing, it needs a new way to combine with modern. Accordingly, this research intends to use the scientific approach to inherit and apply it. The objective of this research is to study CTCH with science manner through CTCS. This dissertation aims to present the digitization inheritance methods and application, as the abstract that contains conservation, improvement, development for CTCH.

1.5 Method Overview

This dissertation is following the logical sequence, as shown in Figure 1-4.

Due to the complexity and multi-discipline of CTCC and CTCH, it needs to be solved through a combination of the macro and micro levels step by step. Level 1, summarize the phenomenon, sorts out the problem, and the direction of solving the problem. Level 2, takes out the ways and approaches to solve the problem through literature review. Level 3, based on the above two Levels, obtains the research approaches and content of this research. Accordingly, the macro level which is the guidance outline for this study as the level 1, in the macro development process that included the research approach of Conservation, Improvement, and Development (CID) methods which are level 2 and level 3.

For the micro level, the keyword is the data, the practice method of the whole dissertation, it is mainly about the data level that is the systematic and cyclic processing flow. The meaning of the conservation method proposed in chapter 4 is to extract and quantify the data of CTCH. The meaning of the improvement method proposed in chapter 5 is to optimize and reprocess the original data. The development method is proposed with Chapter 6 and Chapter 7, which provides the operation of data to make it to be renewable data that can be updated, transform, used, accumulated, and circulates in this way for the CID method in this dissertation or other related work.

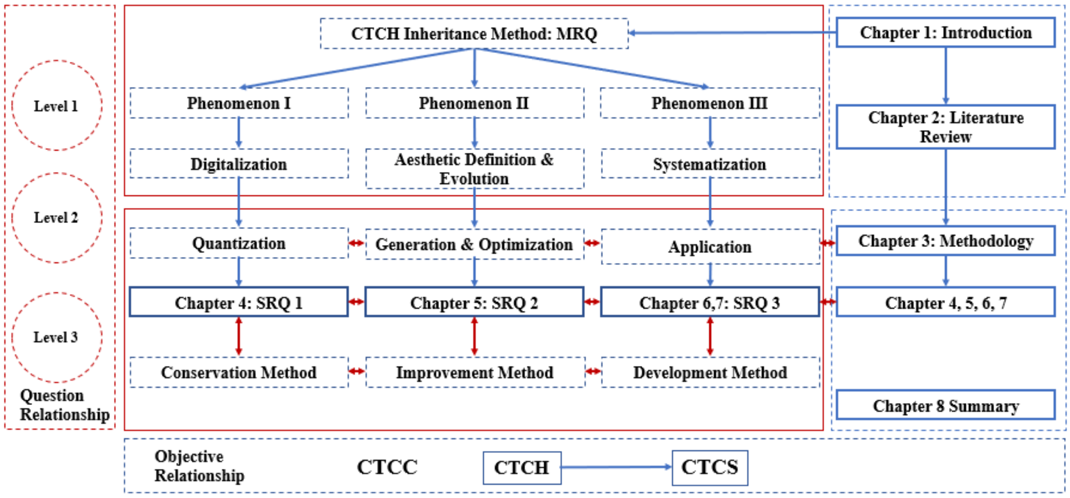


Fig. 1-4 Research Logical Sequence

1.6 Novelty

In this dissertation, to solve MRQ and three SRQs, it had used 3 chapters to do the preparatory work, and 4 chapters to do the concreteness work within the main body. Accordingly, the novelty of this dissertation mainly includes three aspects：

1.6.1 The Method for Digitalization Features of CTCH

CTCC is the intangible cultural heritage and protecting and keeping it that is a hard problem. Digital processing technology is an important means of information preservation. In terms of the inheritance and development of intangible cultural heritage, the extraction of color features and data processing have brought new manner for it. On the other hand, even though data is the foundation and the most reliable information carrier, a rigorous data model always faces difficulties when it comes to describing people's complex emotions and feelings about colors and color scheme relationships.

To better conserve and inherit CTCC and CTCH, it is essential to follow and combination the modern chromatic science and color standards. In this part, a method had been proposed which focused on the extraction of CTCS. Secondly, the results that compare with the existing color extraction methods, and brain wave test, proved that the method in this study can obtain more acceptable visual perception from participants, and the results extracted by the work can cater to the aesthetic cognition of contemporary people. Third, through the extraction method the CTCH database, and website application had been built up, which can offer the practical tool for the CTAW.

1.6.2 The Architecture and Model for Generation and Optimization CTCH

CTCC has a history of thousands of years. CTCC is strong historical characteristics some parts of it do not suit contemporary people's aesthetics, and it needs to be integrated into modern society in a new way.

To inherit and develop the CTCC, in our view that the CTCC should meet the needs of the development of the times and the cognitive and aesthetic characteristics of contemporary people. To achieve the aim, in chapter 5, the improvement method and process to inherit and develop CTCH are proposed. The algorithm architecture in this method refer and combination with the architectures included the Lasso regression model (S. Lin & Hanrahan, 2013b), the Neural Image Assessment (NIMA) model (Talebi & Milanfar, 2018), and the Wasserstein GAN gradient penalty (WGAN-GP) model (Gulrajani, n.d.) respectively, its main function is to generate and optimize the CTCS that carter with the aesthetic perception of modern human, and provide the model and algorithm. This integrated process absorbs the advantages of the three models, improves the efficiency compared with using each model alone and preliminarily solves the comprehensive problem of generation and optimization of Chinese traditional color scheme.

1.6.3 The Interactive Application and Development Method for Inheriting CTCH

Color harmony is an abstract perception of the appearance of things by humans. It needs to be expressed through human language or physical carriers through human visual perception and abstract thinking processes. CTCC as intangible cultural heritage is too complex to understand and use in real projects, it needs lots of professional knowledge that is hard for most people and the public. To better make people comprehend the historical background of CTCC, and make CTCH easy to use.

In this part, the research workflow of the color matching application and VR application are based on the quantitative model of perceptual factors and explore how to use the theory methods of CTCH in practice. More precisely, a website interactive system had been constructed. The purpose is to facilitate the collection and processing of perceptual quantitative data of CTCS which are selected by people and help people comprehend the knowledge of CTCC and CTCH. Its significance is to facilitate the connection with quantitative and qualitative methods for CTCH. and it provides the application method that combines theory and practice for CTCH.

1.7 Contributions for Knowledge Science

Knowledge is divided into explicit knowledge and tacit knowledge, explicit knowledge can be displayed, tacit knowledge is hard to formalize. The CTCH is the tacit knowledge and intangible cultural heritage, it is the complexity to inheritance.

This dissertation through interdisciplinary approaches proposed a systematic methodology, to set up the method of digitization inheritance and application for CTCC and CTCH that included the conservation method, improvement method, development method namely the CID method. This methodology is the method of inheriting intangible cultural heritage and it is also the measure for the continuation of knowledge development.

The contribution of conservation method for Knowledge Science. The method is proposed to color scheme extraction for the image of CTCS, it supplies the foundation database for CTCH, it is protection manner for knowledge and intangible culture heritage.

The contribution of improvement method for Knowledge Science. The method can be used generation and optimization CTCH, it is the method of transformation procedure which from the abstract to the concrete for aesthetic knowledge and tacit knowledge.

The contribution of development method for Knowledge Science. The method is proposed for learning knowledge of CTCH and CTCC, through those methods that can guide people know how to use it and more comprehend with the CTCH and CTCC. Its significance is to facilitate the connection the knowledge with the CTCH.

As consequently, this methodology offered the methodology and practical manners with research cases for intangible cultural heritage research which could be a reproduction.

1.8 Outline and Structure

This research had been used 8 chapters within the main body of the dissertation, as follows:

Chapter 1 Introduction.

This chapter introduces an overview of this dissertation it illustrated why CTCC and CTCH should be inherited, it includes the background of this study, problem statement research questions, research motivation, objective and aim, novelty, and the whole structure of the dissertation. This chapter briefly explains major work produced.

Chapter 2 Literature Review

This chapter provides the literature background of the CID method which was proposed in the dissertation for inheritance CTCH with three aspects. Through summarizes the theories and principles of Chinese traditional color harmony and western color harmony through the method of comparison, to provide the basis and groundwork for the following. Simultaneously, summarize the results of the previous research, and get the specific methods suitable for this study. The main purpose of the literature review is to explain the research theme from two aspects of research results and theory.

Chapter 3 Research Methodology

This chapter described how the CTCH inheritance methodology had been proposed for this dissertation as the systematic method, which includes the thinking process, the research design, methods, and research procedures of each chapter. This chapter specifically describes the thinking process and way of studying how to acquire and answer the question. This chapter uses the progressive approach to deduce the CTCH inheritance methods from the whole relationship to the branch relationship.

Chapter 4 An Extraction Approach of Chinese Traditional Scheme Colors Based on Chinese Traditional Artwork

This chapter had proposed the method that focuses on the extraction of Chinese traditional color scheme to quantization and digitation approach for CTCH. Secondly, the results that compare with the existing color extraction methods, proved that the method can obtain more acceptable with visual perception. Finally, through the extraction method, the CTCH database and website tool of application had been built up.

Chapter 5 Contemporary Chinese Traditional Color Harmony Aesthetic Renew Approach Based on the Deep Learning method

This chapter is mainly an extension and in-depth study of chapter four. The research content of this chapter is based on the three model architectures, which are the model of the Lasso regression, the NIMA, and the W-GAN_GP, constructing the generation model and the optimization model of CTCS, and then proposes the item specific methods and procedures for the CTCH inheritance. This process and results can provide an algorithm architecture basis for the subsequent interactive research system.

Chapter 6 An Interaction Website Application of Chinese Traditional Color Harmony: The Case of High-Speed Railway

In this chapter, the high-speed railway interactive website color scheme system is based upon CTCH and CTCS. the work of the chapter is to explore a method of integration and blending, namely color quantification and interactive design, to expand the scope of application of CTCS systems. The aim is to reduce the dependence of color scheme design on professional knowledge, improve the efficiency of color scheme design, obtain train color scheme data with CTCS characteristics, and carry out preliminary quantification of perceptual factors.

Chapter 7 A Virtual Reality Interaction Auxiliary Learning Application of Chinese Traditional Color Harmony

In this chapter to assist the public to learn and understand Chinese traditional culture, an interactive application of CTCH and Chinese traditional color is proposed. First, two semantic relations are established, which are the relationship between sensation image and CTCS, Chinese traditional color, and Chinese Tang poetry. Based on the data of relations, an interactive visual reality application is established, which could help people understand and comprehend the cultural meaning of CTCC.

Chapter 8 Conclusions and Prospects

This chapter mainly elaborates on the overall work conclusions, implications, limitations, of the dissertation. The last chapter answer the SRQs for MRQ presented. The whole method includes theoretical and practical implications. Limitations and recommendations for future works, also consider of inspiration for the subsequent studies.

CHAPTER 2 Literature Review

2.1 Review for Digitalization

2.2 Review for Aesthetic Evaluation

2.3 Review for Systematization

This chapter provides the literature background of the CID method which is proposed in the dissertation for inheritance CTCH. The overall structure of the literature review is shown in Figure 2-1. To better illustrate and review the content of each part, which involved the theory and related work are separated into each section correspondingly.

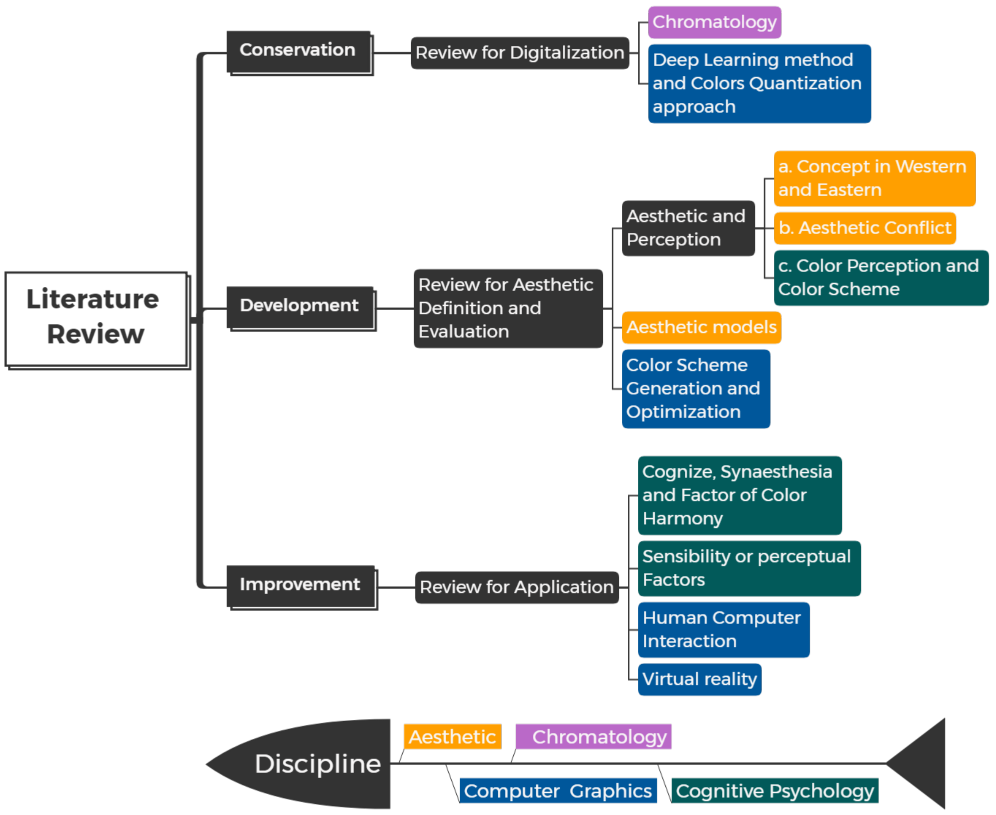


Fig. 2-1 Structure of Literature Review

In review, by comparing the aesthetic views, theories, principles from the East and the West, the standpoint and conclusion are summarized in relevant work with interdisciplinary. Simultaneously, the concrete methods which are suitable for the chapter of the dissertation are obtained to provide a theoretical basis and methods for the work. In conclusion, the major purpose of the literature review is to amplify and illustrate the literature review and review of the dissertation from theory, method, and conclusion. The three aspects are as follow:

2.1 Review for Digitalization

Color has been widely used since the emergence of human beings. with the development of human society in different periods, color also plays a very important visual role in different fields. From prehistoric murals for recording to modern paintings to express aesthetic and artistic concepts. From the covering to cover the body to all kinds of apparel to convey the fashion manifesto in modern times. From the color and logo to distinguish the nature of the tribe to the national flags of countries in the modern world. Color culture and color harmony had been and will always be accompanied by the development and progress of human society.

With the gradual establishment of the modern scientific system, color has been scientific, systematic. Driven by the development of science and technology, color and related disciplines are gradually refined, color is integrated with other disciplines and a new system is developed, such as color and optics, which promotes the standardization and systematization of color. Color and psychology promote the humanization of color harmony theory and color collocation. Finally, when the computer science emergence, color, and related research has been promoted to another dimension, which can solve the huge amount of data problems in color research in a more intelligent way.

How to inherit the CTCC and the CTCH scientifically will be the purpose of this literature review. Therefore, to solve the problem of digitalization, the view in this work had been considered that, for the inheritance and development of Chinese traditional color culture, it is essential to adopt the mixture approach to seek the way and study the CTCC and CTCH with chromatology with computer graphics and other related disciplines. The literature review in this part will involve two aspects: Chromatology, Colors quantization approach.

2.1.1 Chromatology

Western chromatology research, since Newton, released color from the light which lead the Western scholars entered to a new realm of color research (Kita & Miyata, 2016). The Munsell color system had been founded by Munsell A.H., In 1905. The Germans Wilhelm F. Ostwald had published the color system of mixed color method in 1917 (Gong et al., 2017a). In 1983, Andrews through the Munsell Color Tree shows the pleasant visual phenomenon in the form of color combination (Granville, 1987)， This sensory phenomenon is considered to belong to the category of color harmony (Gong et al., 2017a). Subsequently, the theory of red, green, yellow, and blue that are the "four primary colors" was founded. The significance of this research content is that it covers the fields of physics, biology, and psychology, and provides a new direction for color-related research (Jacobs & Hustmyer, 1974). Since then, the clue of the western theory of color harmony began to take shape (Szabó et al., 2010).

As the beginning of the standardization of modern oriental colors, the Japanese Color Research Institute published Practical Color Coordinate System (PCCS) in 1964 (Chuang & Ou, 2001). Subsequently, the Swedish Natural Color System (NCS) was established, which is based on the theoretical framework of the Oswald color system and added psychological research methods. For now, the most used color system is the PANTONE color system which is the commercial use. The Chinese color system began with the book "Chinese Color system", which was completed in 1993, and then established the Chinese architectural color card CBCC. It was not until 2003 that the China Textile Information Center launched the research on the Chinese applied color project, and established the Chinese national standard GB/T21898-2008 which is the textile Color representation method, and the ***Uniform color space and color difference formula (GB/T 7921-2008).*** Until 2015, China has published the latest national color standard which is the ***Names and colorimetric characteristics of traditional colors in China (GB/T 31430-2015)***

2.1.2 Colors Quantization Approach

In the past few years, different scholars have proposed a variety of automatic color theme extraction methods. Generally, the major methods for color extraction of the image are: A. Median Cut Method， the problem is that under some conditions, cuboids in color space are large but contain only a small number of pixels. B. Octree Method， the number of leaves cut each time is uncertain, but only the new one is added, which leads to the number of swatches not always satisfied. C. K-Means method， When the random selection method is used, the center point selected in the iterative process is far from all other data and eventually leads to isolation.

The work proposed an important beginning, in which the color themes based on images are compared with those extracted manually by people, and the color extraction method based on human color theme data is used (Lin & Hanrahan, 2013a). The work proposed the concept of emotional color theme is introduced, the color emotion theory is introduced into color theme extraction, and a novel emotional color theme extraction framework is proposed (Liu & Luo, 2015). the method of color theme extraction for fabric images is expanded by one step of image saliency (Liu et al., 2016). The research extracts the features of the CTCC Yuexiu color system by the K-Means clustering method (Zhe et al., 2019). The work that improved palette extraction method based on k-means clustering and analyzing image color hue and saturation components is proposed. The algorithm improves the saturation of representative colors and the effect of color extraction of small detail images. the study through calibration color of each photo is converted to the CIE Lab color space, and the representative color of the building is determined based on the selection of k-means clustering (Ruxpaitoon & Lertrusdachakul, 2019).

The method that the color theme can be extracted by using the supervised method of regression model training based on the user-defined color theme (Ciocca et al., 2019). It is worth noting that the research method is more like psychological research (Liu et al., 2016), through human behavior experiments to obtain training data, and then adjust the parameters for the simulation. In his work, 79 feature variables are extracted from the image and multiple regression is carried out, and the results can better fit the results of human selection (S. Lin & Hanrahan, 2013b). This training model can provide visual results which simulate human visual cognition and are closer to human feeling. Through the reproduction of the above methods, this research found that the extraction results of CTCS are not ideal that some colors are not correct and some are not suitable, but the work of Lin has significance reference meaning for this research.

2.2 Review for Aesthetic Definition and Evaluation

Human beings continue to pursue beauty, exploring and studying beauty in various ways in different periods. They try to give new dimensions and definitions to beauty by different means and ways, but these definitions are full of opposites and unity. Western aesthetics has explored beauty through philosophical speculation and mathematical formulas since ancient Greece. On the other hand, oriental aesthetics pursues the natural beauty of the unity of man and nature from the CTCC. With the development of society and the satisfaction of basic matters, people begin to pursue the pleasure of the spiritual dimension. As stated in Maslow's demand theory, people's demand is divided into stages.

On the contrary, there have been differences in the definition of aesthetics since ancient times, what is beauty and what is the best way to express beauty. Various theories and schools hold their own opinions. Since the cognitive theory, color harmony theory has been proposed, an aesthetic model has been established, neural network, deep learning method, and other disciplines have been developed. It gives more extensive exploration space for aesthetic definition and aesthetic evaluation.

As consequence, how to construct a balanced way of beauty and evaluate CTCH will be illustrated in this part of the literature review. Three aspects of related work are mainly involved in Aesthetic definition and evaluation: 1. Aesthetic and Perception. 2. Aesthetic Models 3. Color Scheme Generation and Optimization.

2.2.1 Aesthetic and Perception

a. Concept in Western and Eastern

Plato, “time is a moving image of eternity.” (Abrams, 2021). Beauty is objective and comfortable, it is external to human beings, and it is an objective entity that does not transfer human beings all the time. When Pythagoras says that something is beautiful, it is because it conforms to a law of beauty, which is real and the same all over the world, and this law of beauty is a mathematical proportional relationship. If a thing accords with the harmony of mathematical proportion, it will produce a sense of beauty. For example, the reason why music is good is that it accords with mathematics when the chord length of two notes is a simple integer ratio. The sound produced by playing at the same time or continuously is harmonious and pleasant, or in the field of architecture and sculpture, if we design architecture and sculpture according to the golden proportion, it will show a sense of beauty. The ratio of the golden section is about 1.618. There is a kind of objective and comfortable law of beauty. If it conforms to this law of beauty, it belongs to beauty, otherwise, vice versa.

On this basis, Plato further explained that the law of this kind of beauty is a kind of spiritual existence, which is called "idea". It holds that spiritual existence is higher than material existence, because the matter is immortal, and spiritual ideas, like mathematics, are immortal, and all immortal things in the real world are imitations of immortal ideas, so they appear to be beautiful. The aesthetic ideas of people have differences and are divided into different levels. According to Plato's view, it is still a matter of the matching relationship between matter and spirit. The figurative aesthetic is not through any formal abstraction, but a direct aesthetic to the concrete material itself. Plato also believes that these are all low tastes, while the advanced aesthetic is an aesthetic activity in which human beings use spiritual rationality and capture the same as spiritual ideas. On the other hand, elegant art is a kind of abstract art, which pays attention not to any specific objects, but to a kind of formal beauty, through which people pursue a kind of pure spiritual communication. The difference between people's aesthetic taste is real, because the concept of beauty is a kind of objective and comfortable spiritual entity, and people's aesthetic taste will be disturbed by sensual desire, so we should improve our aesthetic taste. It is vital to get rid of the hijacking of sensuality and appreciate pure spiritual beauty through reason. The aesthetics are divided into superior and inferior, that aesthetic is not entirely an objective activity, but also has subjective elements in it (Perlovsky, 2014). The aesthetic is the human being as the subject in aesthetic, although human aesthetic has subjective factors, humans have a kind of congenital common sense for aesthetic. Kant divides aesthetics into two kinds of tastes, reactive interest, and reflective interest, the former is empirical interest and inevitable interest. The latter is rational interesting and free interesting. The first kind of interest does not have universal inevitability, it is a matter of individual aesthetics, and this kind of aesthetic taste is a more sensory pleasure.

In the view of Hegel, beauty is the sensuous presentation of the idea; beauty is the manifestation of the idea in sensuous form; In the aesthetic system of Hegel, natural beauty stands as a lower basic condition of artistic beauty, which is the sensible appearance of idea since it rarely gets vigor perfusion (Hegel, 1975). Western aesthetics is used to express beauty through fixed formulas or equations, from impersonal ways to express that beauty is an immutable truth. On the other hand, western aesthetics is emphasized beauty as subjectivity which is from the person.

In the contrast, in traditional Chinese philosophical values, the philosophical concept of Yin-Yang and the five elements is the foundation of all things in the world, it is a kind of the concept of psychology and philosophy (Louise, 2015). It has lasted for more than 2500 years in China that has been deep-rooted in Chinese blood and mind. The five-form, color combination is the most harmonious Chinese traditional color. Commonly used expressions, in the traditional five element colors, five colors refer to the five color categories that are usually expressed as blue, red, yellow, white, and black (M. S. Lee et al., 2012).

The black and the white symbolize Yin-Yang in the theory， and it means two-side of the world which are constructed by Five-Elements, It's an interpretation of the ultimate cycle for all things in the world, the two sides of matter going round and tangling each other infinitely.

The surface meaning of Yin-Yang is the opposites, the deeper meaning is the combination of opposition and unity. In the traditional Chinese color harmony method, black and white are a combination with other colors to achieve color brightness and purity. The change of saturation produces different ways of color matching. CTCH is based on the observation of nature and the accumulation of experience. In Chinese ink painting, this philosophical thought is shown as the change of ink, and it is also described as colorful black or white, while in ink-art, the ink is divided into five changing dimensions.

2.2.2 Color Perception and Color Scheme

Color harmony is a complex issue that contains a variety of areas (Ou et al., 2011). Color is the visual effect stimulated by light through the human eyes delivery into the brain (Ji et al., 2020). The influence of color on human senses has three levels. The first level is visual perception, which is mainly affected by the physical properties of perceptual objects and is closely related to color perception. The second level is psychological perception, and the result of perception is influenced by the individual factors of the experimenter. The third level is based on the interaction of the complex relationship caused by the interaction of the first two levels (Nemcsics, 2012).

As the basic meaning of the color scheme is the visual effect produced by combining more than two colors. The visual effect produced by different color elements is called a color scheme through the principles of balance, emphasis, contrast, prosody, dominant color, auxiliary color, etc. (Nemcsics & Takacs, 2019). If this kind of color scheme is formed a pleasant feeling from people that belongs to beauty, it shows that this way of color scheme belongs to the category of color harmony, and color harmony is a kind of aesthetic evaluation of the color scheme. (Granville, 1987),(Hsiao et al., 2008).

Meanwhile, people's aesthetic perception of color schemes will be influenced by race, culture, social experience, gender, age, and other factors. (Q. Jiang et al., 2019). Color harmony is a kind of abstract perception of the appearance of things, which can only be expressed by human language or physical carrier through human visual perception and abstract thinking process(Hsiao et al., 2017). Notably, chromatism establishes the aesthetic model of color scheme model to interpret or define the criterion of color harmony.

2.2.3 Aesthetic Models

The related research on color harmony mainly includes color harmony, color preference, and color composition. Starting from Ostwald, colorists have tried to summarize the general law of color harmony. The color harmony is equivalent to the order which should follow the mathematics scale (Granville, 1987). Moon and Spencer had grouped colors into four categories according to the color contrast, the atmosphere similarity, the ambiguity, the comparison (Moon, 1944). Hard and Sivik proposed a color harmony factor model (Hård & Sivik, 2001).

The harmonious color scheme based on the color wheel mainly contains six contents as follows (https://paletton.com/), part of the case is shown in Figure 2-2:

1. Monochromatic collocation, this method uses only one color or hue. Just pick a point on the color wheel and use changes in saturation and color values to create changes. The advantage of this scheme is that the color can be matched.

2. Analogous collocation： It refers to the use of adjacent colors in the color wheel, such as red and orange.

3. Complementary collocation： Complementary colors are opposite to each other in the color wheel, such as blue and orange. To avoid oversimplification of the complementary color scheme, some colors with different saturation are introduced.

4. Adjacent collocation： Match with adjacent colors on both sides of the relative color. It can improve the comparison and make it more interesting.

5. Triadic collocation： Three uniformly distributed colors are used to form a perfect triangle on the color wheel.

6. Tetradic collocation： The color used in the quad collocation forms a rectangle on the color wheel.

Those kinds of color harmonious collocation above can greatly facilitate non-professionals to generate color collocation, but this fixed pattern will not produce a unique cultural beauty. Additionally, the nature of color harmony is defined by people's subjective judgment, and it is a concrete conclusion drawn by people through the accumulation of experience (Nayatani &

Sobagaki, 2002). However, the empirical definition and evaluation of color harmony are limited, and the color is affected by many aspects, the people who judge whether color belongs to a harmonious individual, the conclusion will be very different (Ou et al., 2011). With the emergence of neural networks and deep learning objective evaluation becomes possible that can learn the human experience into its logic and operation mode.

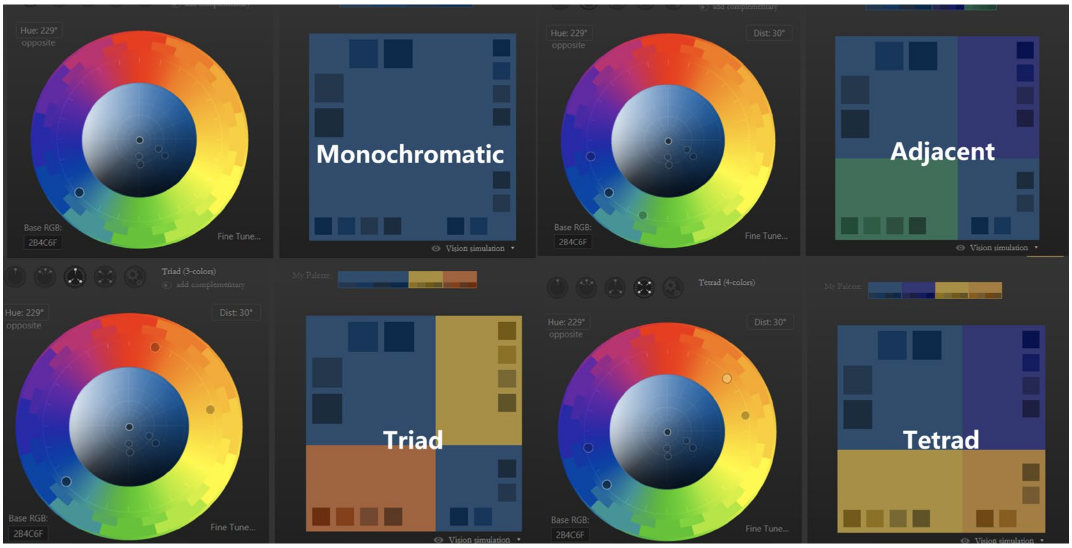


Fig. 2-2 Harmonious Collocation

2.2.4 Color Scheme Generation and Optimization

It is the difficult problem for non-professional backgrounds people to create a color scheme that caters to aesthetic criteria and concerning designers create a suitable color scheme that can gain ratification from most people, it is also an uneasy thing. Additionally, the aesthetic value and conception of the CTCH and the CTCS were created in ancient times, some of the aesthetic concepts are not suitable for contemporary people. How to optimize CTCH with a suitable approach will be the motivation of the literature review in this part.

a. Color Scheme Generation

The research work is based upon the color harmony principles that involved familial factors and rhythmic spans from conventional color theories, in the work the tool had been proposed which could make people create harmonious color schemes only with several steps (G. Hu et al., 2014). The method allows participants to obtain suitable color schemes easily and effectively through the interactive genetic algorithm and four similarity search functions (ISHIBASHI & MIYATA, 2015). The research proposed a model of six-variable. The color combinations generated from this model can express the specific parameters of the six-variable involved the value of saturation, a representative value of lightness, the span of hue, the span of saturation, and the span of lightness (G. Hu et al., 2015). The research proposed the rating prediction model which had been trained by the preference color dataset from the human. This method used the model to rate color combinations that consider human aesthetic preferences (Kita & Miyata, 2016). The method proposed an automated approach to creating a color scheme through the multi-objective interactive genetic algorithm. The color scheme generated by this method can convey desired personality impressions, and express designers' preferences (Wu et al., 2018). The research builds up a neural network-based upon human emotion and feeling with correlation analysis and factor analysis(Guo et al., 2020).

b. Color Scheme Optimization

With the development of artificial intelligence, the deep learning method has provided and supplied great help to solve the problems encountered in computer image vision. But the deep learning has not been paid attention, before 2009. Since the IMAGE competition project initiated by Li in 2009 (https://image-net.org/), massive data and tagging content have been gradually established. Until the large dataset for deep learning neural network established by Alex who won the championship of IMAGE competition in 2012, the deep learning method had been valued and developed by leaps and bounds.

Generative Adversarial Networks (GAN) can provide good appeal with enhanced visual results (Gulrajani, n.d.). GAN has produced many popular architectures, as identifying deep network generated (DNG_GAN), (Li et al., 2020), Loss-Sensitive Generative Adversarial Network (LS_GAN), (Qi, 2020), Wasserstein GAN (W-GAN_GP), (Gulrajani, n.d.), etc. These structures have their application fields, among which the WGAN_GP has an excellent generation effect.

Based upon the works above, the view of this dissertation can learn as follow aspects. First, the way of generation and optimization CTCS should use the color scheme preference data from the people, people from China is the best option, due to the traditional concept for any culture that had been in habits and customs inside the people minds, in the more or the less. Second, regard to CTCS such amount that it needs the automatic approaches to generate it. On the other hand, it can train the model and obtain data that learned from experts or professional people will be the better option. Thirdly, compared with the original GAN, W-GAN_gp has a better result (Gulrajani, n.d.), which makes the training data for the network more stable and to the generated image.

2.3 Review for Application Approach

Regarding contemporary society, the relationship between color, human aesthetic, and culture is further strengthened, and the color is in a more important position. Color is not only a kind of aesthetics but also a kind of social and cultural category. Color is an important aspect of natural beauty and traditional aesthetics. (Kawabata， 2004). Color expresses all kinds of human thoughts and emotions in a variety of possible ways. Color has become a carrier of cultural symbols, color and culture are inseparable, and become an important part of the culture (J. H. Lee & Kim, 2007). Color is not only related to itself but also carries social aesthetic and cultural significance (Y. Wang, 2017). In addition, color also has the role of psychological implication, the value of color in the spirit can`t be ignored (Jacobs & Hustmyer, 1974). Color is deeply affecting human emotions and thoughts through aesthetic and cultural activities.

As consequence, how to establish the cognitive and perceptual relationship between humans with CTCC, CTCH, and society systematically, and how to construct the aesthetic way into the concrete application through this cognitive behavior relationship, will be the content of this part of the literature review. This section will contain three aspects, 1. Cognize, synesthesia, and factor of color harmony. 2. Sensibility Factors. 3. Human-Computer Interaction.

2.3.1 Cognize, Synaesthesia, and Factor of Color Harmony

In general, synaesthesia is classified as a human physiological phenomenon. Synaesthesia is such a perceptual experience that one kind of perceptual experience evokes another kind of perceptual experience at the same time, and this evocation is involuntary and has not been consciously processed by the brain (Rouw & Scholte, 2007). But another view of synaesthesia is the sense of unity and common which on a spiritual level that transcends time and space (Julia, 2011).

Regarding color, originates from the principle of color harmony in human observation of nature, the sense of unity produced by basic toning. If a certain hue occupies a large area of the image, it is called the dominant tone or hue, the second volume of hue in the image that is called auxiliary hue. The dominant color and the auxiliary base color play a major role in human perception and emotion (Gou et al., 2021). The image formed by color or color collocation is derived from the enlargement of common elements. Although the image and emotion of color vary greatly from person to person, there is a common phenomenon in it (Solli, 2011). Even though the person comes from different cultural background, the cognition of some colors will not be very large, such as red which is a means of enthusiasm, it symbolizes warmth. The blue symbolizes coldness etc. Nonetheless, as the number of color elements increases, the complexity of perception will also change (G. Hu et al., 2016). The visual proportions of the dominant tone and minor tone of the spatial color scheme are the main factors that form the image of the color scheme, and the visual focus point will also have a secondary impact.

Consequently, it is like the language is formed by logic, the music is composed of rhythm, and whether color collocation is harmonious or not, depends on the certain proportional relationship between color and human vision and psychological behavior. Maybe it can be called the universal value of color, but it needs to be emphasized that this is only a phenomenon in cultural commonness, not an absolute definition or rule for color harmony.

2.3.2 Sensibility and Perceptual Factors

The concept of being people-oriented has become the core idea in various fields. Human perceptual factors have become an important discipline in academic circles. Since the Kansei Engineering establishment of has pointed out the direction for solving perceptual problems related to human beings (Matsubara & Nagamachi, 1995). Thereafter, the multitude of researches are based on the KE method emerged in an endless stream. As the study explored the perceptual requirement of consumers， the perceptual requirement of interior color was obtained using the perceptual engineering method. The perceptual data was processed with reduction dimensionality (Of & Design, 2019). The study aimed at the problem that the color image was not clear in the design process of elderly products， through the KE method， the elderly users were taken as the subjects to perform psychological response test on a household products color scheme using the semantic difference method (Design, 2018). The study used environmental psychology research methods and the KE method, confirming that freely chosen images with word prompts, proved the potential for identifying sensation requirements (Yoshida et al., 2018). The view of the research proved that visual color is the most important. The research on the visual color matching of KE has become a project that has an important impact on the research and development of related fields in the future (Y. Lin, 2019a).

Additionally, the human perceptual experience can be divided into five categories: aesthetic experience, emotional experience, social experience, cognitive and functional experiences, which can be summarized into three levels; feeling, behavior, and reflection. This point of view provides the theoretical basis for the study of color harmony.

2.3.3 Human-Computer Interaction

Human-Computer Interaction (HCI) adapts to people from the computer to the computer, and the interactive information gradually evolves from a single input and output process to a multi-dimensional input and output information interaction process. The initial and lasting technical focus of human-computer interaction is the concept of usability which is definition usually includes entertainment, happiness, collective efficacy, aesthetic feeling, tension, enhanced creativity, mobility, support for human development, etc. The real starting point of HCI from the publication of the book that namely *the psychology of Human-Computer Interaction* (Card, 2018).

Similarly, due to the further expansion of the subject field of the integration of cognitive science into human-computer interaction. As the interdisciplinary research, the human-computer interaction had been beginning with the project of cognitive engineering (Carroll, 1997), (Treadaway, 2007). Additionally, with activity theory into HCI that has sublimated nature of HCI (Bazerman, 1998). The connotation of HCI is not only to explore the relationship between man and computer but also to describe how the change of consciousness is directly related to the current material and social conditions with people. This view makes individual consciousness a situational phenomenon, in which material and social background are very important. One of the fundamental reasons, why activity theory is related to technical design and evaluation is that it emphasizes that artifacts are an important intermediary of human experience. According to the activity theory, the artifact is the product which base on human experience that from abstract concept to concrete matter, and it needs to be verified in social practice (Bazerman, 1998).

At present, HCI had been involved in various fields and disciplines, the research and practice of human-computer interaction involve and draws lessons from the advantages and disadvantages of multiple disciplines. The essence of human-computer interaction has become more extensive and diversified than computer science itself, it has great value for interdisciplinary research. Consequently, as the interdisciplinary application field, HCI is the key to social and scientific development in the future.

The major reasons are as follows:

1. Predictability, the behavior of specific things and people can be predicted at some levels and dimensions through data accumulation and the learning process.

2. Artificial intelligence needs a huge amount of human-related data, which is required to be obtained through the human-computer interaction process.

3. Auxiliary, the potential of humans as an organism has not been fully developed, and human-computer interaction can help human beings to give full play to their mental and physical potential in the future.

Additionally, with the integration of the field of design science and HCI, user experience design and interaction design based on human perceptual cognition are not only the input into HCI but the output from HCI. To analyze the production requirements and needs between creativity and basic principles in design, as a design process, HCI must have internal logic, and can systematically evaluate and maintain the design, but in the meanwhile, stimulate new experiences and insights. As an extension of HCI, with the maturity of virtual reality technology and hardware equipment, VR (Diemer et al., 2015), there is a new technical way for the study of color harmony. Virtual reality technology can provide real environmental simulation, thus improving the process of emotional experience and establishing the emotional relationship between the environment and people (Riva et al., 2007). The definable interactive environment provides a medium for human-computer interaction. Based on the transformation process of human sensibility and experience, more potential research contents will be provided for human-computer interaction (Computer, 2005). As Conclusion, from the view of this research think that the CTCC and CTCH Inheritance method can be through the approach of HCI to achieve the final aim which is the transformation process of human sensibility and experience.

CHAPTER 3 Methodology

3.1 Research Design

3.2 Research Method

3.3 Research Procedures

3.4 Procedures

3.5 Data collection approaches

This chapter introduces the overall research methods for this dissertation in the way of methodology. Primarily, it explains how research questions emergence which is the thinking process with the complex question for the method of digitization inheritance and application. Subsequently, through the summary and analysis of the literature in various areas with keywords, the top-level method and branch method are reconstructions that are the integrity method for this dissertation.

3.1 Research Design

This dissertation through the qualitative analysis of "why" to further quantitative research, to solves the specific problem of " What is "," for Who " and " How to ", and forms the whole idea struct in methodology, to expand and deepen the research conclusion utilizing the application system. As consequence, the process of problem abstraction can be simplified as follows: First, summarize the central idea through the simplest words. Second, use the simplest sentences to express concise concepts. Third, based on the concept statement to reconstruct the whole method. The thinking process is shown in Figure 3-1.

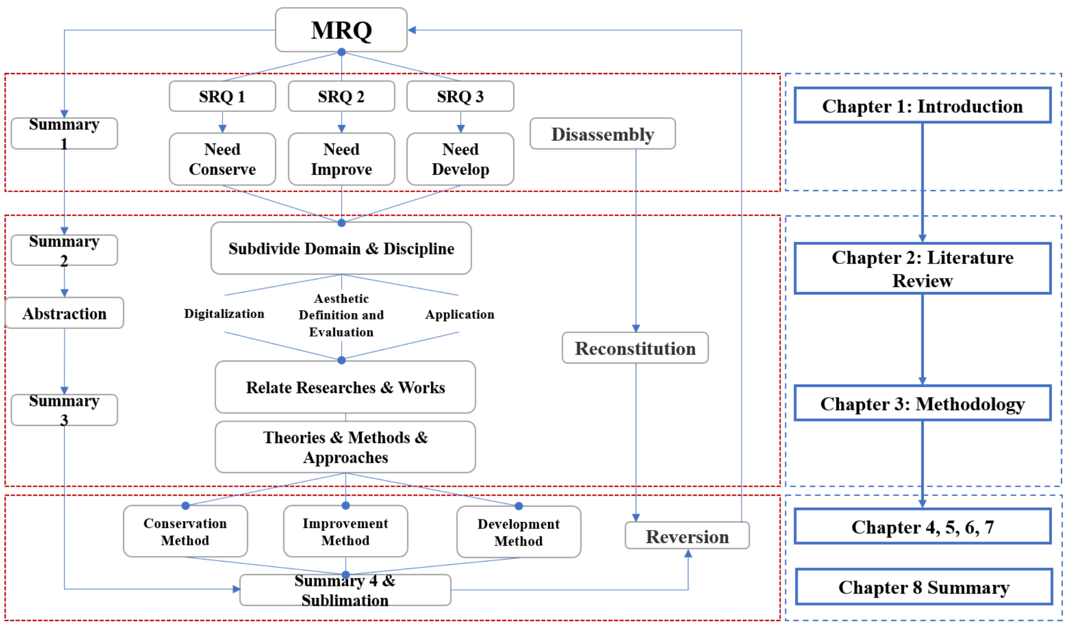


Fig. 3-1 Research Thinking Process

Why do this study?

CTCC has lasted for a thousand years, in which CTCH embodies the Chinese traditional aesthetic concept and Chinese traditional philosophical value. As the intangible culture, CTCH drifts with thousands of years of wind and rain, and many cultural venues and cultural phenomena are no longer complete. In addition, with the process of modernization, CTCH is faced with many problems, such as how to integrate with the modern scientific system and how to improve itself, how to evolve or improve based on its aesthetic system to be more cater to the aesthetic of the modern publications, and how to through modern media to make more people understand the aesthetic of CTCH, etc. Consequently, according to the problems, this dissertation expounds and summarizes one MRQ and three specific SRQ, and constructs a series of solutions to the problems in this dissertation. Undoubtedly, only by protecting the past, that can we better develop the future.

What is it?

For the definition of CTCH, my view think that no expert or scholar can simply use the theory or research result to explain or illustrate the accurate definition, due to CTCC and CTCH being extremely complex, it involves too many aspects and disciplines. But the definition of this dissertation, in work view, is meaning of inheritance is the process of accumulation and re-creation for knowledge. Humans are namely human because they create and accumulate knowledge while maintaining their survival and linebreeding. Generation after generation of human beings create knowledge that belongs to their time and period, some of the knowledge which is recorded in literature, preserved in practice, or taught in words, and passed on to the next generation, opening the wisdom of the next generation. Enlighten the creation and production of knowledge. The creation and production of knowledge are continuously continued and passed on from generation to generation. That makes the various culture can inherit with the process. As an intangible cultural heritage, CTCC and CTCH still shine brightly after wind and rain. CTCC has a history of thousands of years which can be date back as early as 1600 before the Common Era. The CTCH can be sorted through the data level for the future gradually.

Who is the server target?

The service object of this study includes three aspects. Firstly, the major service object of this work is the public. It is hoped that the research content for CTCC and CTCH, offers an operable and entertaining application that could help more and more people comprehend and learn it. Secondly, the minor service object of this work is the inheritor. It is hoped that the CID method proposed by this dissertation could be used as the case for a different culture. Any culture is a treasure for the human being, no matter how small it is. Thirdly, it is hoped that through basic dataset had been struct and interdisciplinary approach in this dissertation, to provide a method that could be used for the reference. In my view believes that the combination of art and computer will be the major direction of innovation for the future, which is transforming people's thoughts and concepts into data that systems can learn and operate.

How to attain the final aim?

The literature is collected and sorted out by keywords, and the literature is analyzed by CITESPACE software which is the Literature analysis and data visualization tools, and the contents of literature abstracts related to CTCC and CTCH are collected in a broad sense and sorted out in a narrow sense. Construct the top-level structure and details of this paper. And form the theoretical basis and solutions. In the dissertation, four chapters had been used to build up the whole methodology which is mainly in way of conservation, improvement, and development.

3.2 Methods

Due to CTCC has a long history, it is numerous and complicated, and there are great differences in historical stages with it. Therefore, it is difficult to study just through the words and literature for theory research, or in a single area simply. Based upon the content and works above, in the opinion of this work, CTCH needs to be union the review of literature materials and combine with modern color quantization standards, using the interdisciplinary method. More importantly, it need be to quantify and digitize through new technologies to extend the research content and works.

CTCC is the intangible cultural heritage and protecting and keeping it that is a hard problem. Digital processing technology is an important means of information preservation. In terms of the inheritance and development of intangible cultural heritage, the extraction of color features and data processing have brought new manner for it. On the other hand, even though data is the foundation and the most reliable information carrier, a rigorous data model always faces difficulties when it comes to describing people's complex emotions and feelings about colors and color scheme relationships.

In the dissertation, a mixed-method is proposed that combines research approaches of the quantitative method, qualitative method, interdisciplinary method, and theoretical with the practical method, as follows:

3.2.1 Literature Review and Bibliometric Analysis

In this part, by analyzing the overall related literature in terms, the processing reduced directions in various related areas gradually. and contact with the relevant literature. This work is mainly based on literature data from the China National Knowledge Infrastructure (CNKI) and the Web of Science (WOS), the CNKI citation index which is abstracting and indexing for more than 500 academic journals covering 25 disciplines among over 2700 academic journals of social science (YU, 2020). through the software of CITESPACE to analyze the bibliometric for this dissertation.

This part uses keywords as the start point to search the relevant works of literature with the keyword the CTCC, based on the quantitative analysis and visualization, qualitative methods are used to analyze and review CTCC and CTCH, to create an overview of the historical context in this field or related works.

a. The Preliminary Search and Data Collection

This research conducted a literature retrieval based on keywords in the WOS database with a time range of nearly 20 years, and the results were not ideal, but several relevant research fields were obtained in the process, as shown in Figure 3-2 (A). Subsequently, the keyword literature retrieval of the past 20 years was conducted through the CNKI database, and 1351 articles were obtained initially. The historical context of research development in this field in the past 20 years is obtained, the literature result of keywords as shown in Figure 3-2 (B).

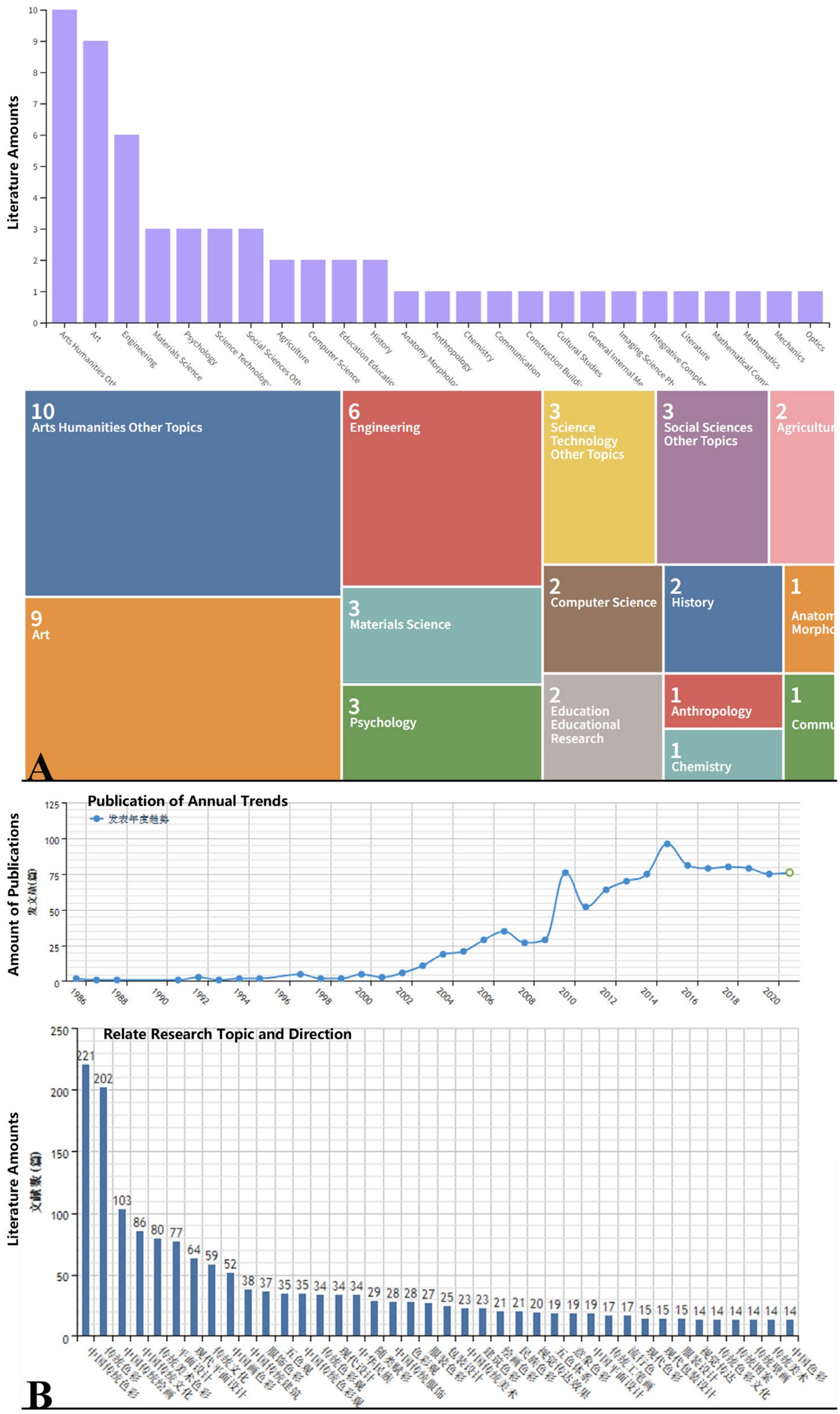


Fig. 3-2 the Literature result of keywords

b. Data Analysis and Result

Due to the overall volume of literature being abundant in the CNKI database, the CNKI database had been selected as the data resource for the literature index and review in this part. This part mainly used CITESPAC software for data analysis, and the strategy is to define the specific literature reference direction of this dissertation through keyword clustering analysis. This work excluded some irrelevant keywords with the main direction of this research, and obtained the keyword Co-Occurrence Network, as shown in Figure 3-3.

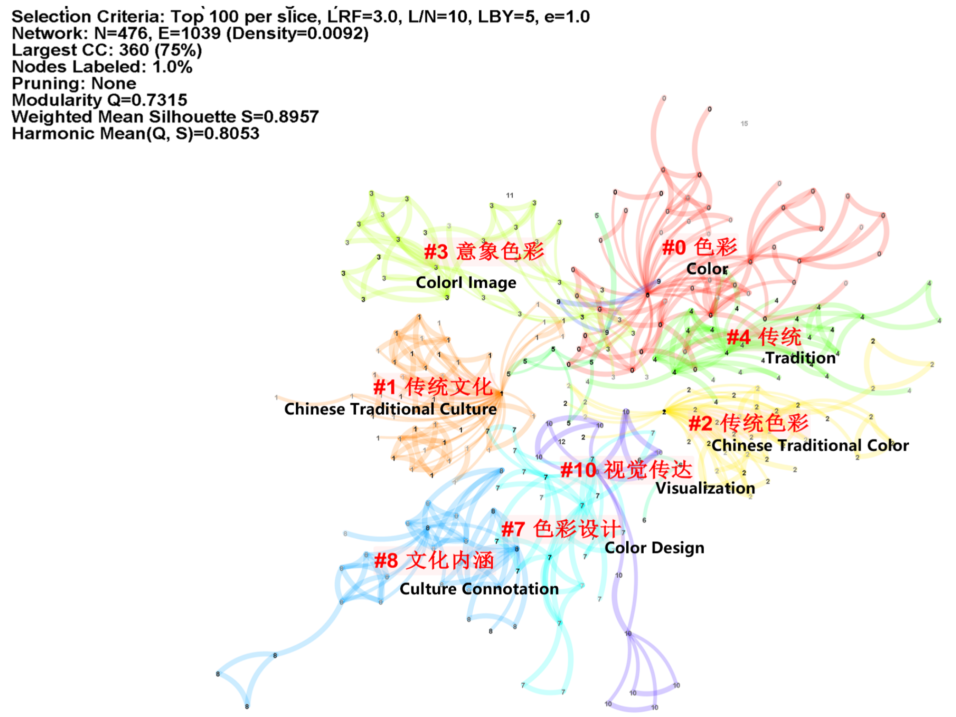


Fig. 3-3 Keyword Co-Occurrence Network

The timeline view of keyword clustering, as shown in Figure 3-4, It shows the focus of the academic articles of various keywords, the research direction, and timeline-related research topic. For example, the red arc is mainly shown the topic of academic articles was concerned on the meaning of CTCC aesthetic, by 2010. The research topic was concerned with the topic of the dominant hue, the intermediate color, and the popular color with CTCC and CTCH, by 2013. The research topic was concerned with the five-color theory and folklore research, by 2018. Base on the keyword co-occurrence network which is the macroscopical category, and literature result of keywords and timeline view of keyword clustering which is specific research context. It can be illustrated that the topic of CTCC inheritance became the hotspot research theme for the Chinese academic community from 2010 to 2020, and it had been focused on the research topic of Five-Color theory and system, aesthetic requirement and difference, color extraction, color concept, and culture psychology, etc. Through this part of the work, it had provided the preliminary guidance line for this dissertation and obtains an elementary shape of the related research situation, research direction, and literature background.

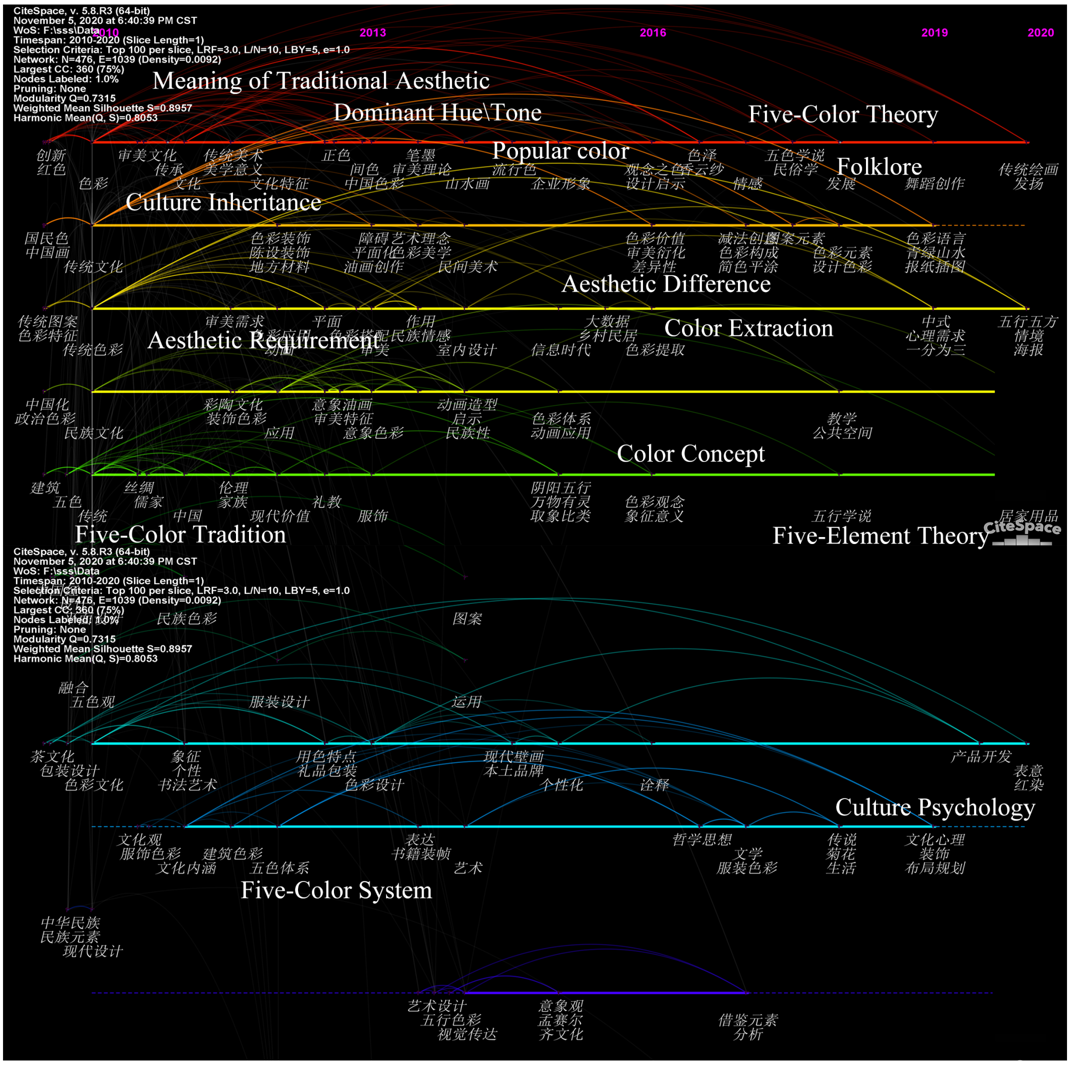


Fig. 3-4 Timeline of Keyword Clustering

3.2.2. Research Ideal

In the work, the CTCS is the research objective. Through quantitative and qualitative methods with interdisciplinary, to explore how CTCC can better be combined with modern color standards and digitalization. The quantified model of perceptual factors, proposed interactive design methods, explored the problems of the CTCC in inheritance, and then demonstrated the applicable color scheme categories and characteristics of the CTCS in the application.

As the old saying goes, practice is the only criterion for testing truth. Therefore, to achieve the final aim, this study should be based on theoretical concepts and principles, and extend and expand the theory by the combination of theory and practice. Transform a relatively abstract theoretical way into an acceptable application which is the knowledge transformation procedure that can make people understand, and use it easily.

This work relied on perceptual factors from humans combined with the chromatic result, aesthetics concept and principle, cognitive psychology, and other theories, through the methods of computer graphics, to seek the common laws and individual preferences of CTCC and CTCH that were built up by the dataset. Finally, set up the inheritance method for CTCC and CTCH that included the conservation method, improvement method, development method.

3.2.3 Research Model

a. Methodology Model

In the dissertation, to solve the MRQ two main model is proposed that are the methodology model and the algorithm model architecture. In the methodology model, to the summary up that are three keywords namely the protection, the improvement, and the development, the whole struct is shown in Figure 3-5.

For SRQ1, the ideal and concept conservation method is proposed, CTCC has a long history, it is numerous and complicated, and there are great differences in historical stages with it. Therefore, it is difficult to study with it, only in words and document literature simply. To better inherit and develop Chinese traditional color culture, we need to union the arrangement of basic materials and combine them with modern color quantization standards, and at the same time, CTCC needs to quantify and digitize CTCH through new technologies. Finally, to achieve the purpose of protection.

For SRQ2, the ideal and concept for improvement method are proposed, CTCC has a history of thousands of years. CTCC is strong historical characteristics and needs to be integrated into modern society in a new way. To inherit and develop the CTCC, in the viewpoint that the CTCC should meet the needs of the development, and the cognitive and aesthetic characteristics of contemporary people.

For SRQ3, the ideal and concept development method is proposed, Color harmony is an abstract perception of the appearance of things by humans. It needs to be expressed through human language or physical carriers through human visual perception and abstract thinking processes. CTCC as intangible cultural heritage is too complex to understand and use in a real project, it needs lots of professional knowledge that is hard for most people. To better make people comprehend CTCC, and make it easy to use.

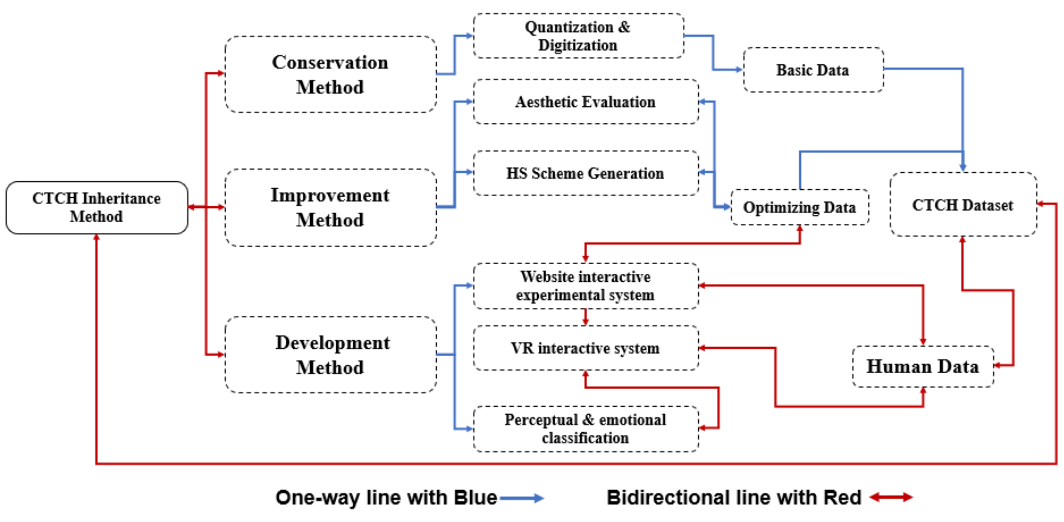


Fig. 3-5 Methodology Model and Data Flow

b. Architecture Model

The SRQ2 is the questions of Aesthetic Definition and Evaluation, the architecture is proposed which involved three models to build architecture, they are the Lasso regression model (S. Lin & Hanrahan, 2013b) which can use to output the result of CTCS in a different level. The Neural Image Assessment (NIMA) model (Talebi & Milanfar, 2018) can evaluate general aesthetic scores with the input dataset and by this work. Through the Wasserstein GAN gradient penalty (WGAN-GP) model (Gulrajani, n.d.), the original image can be optimized and enhanced which can more cater to the visual demand of people. The models in this method refer to the architecture and research of the Lasso regression, the NIMA model, and the W-Gan_GP model respectively, its main purpose is to generate and optimize the traditional Chinese color harmony color scheme that meets the aesthetic perception of modern people with chapter 5 foundation dataset.

c. Data circulation and systematic structure

Please refer to the red line which is the data flow in Figure 3-6.

First, in chapter 4 the basic dataset is built up which was for the conservation method. As a beginning, at least 3000 images of CTCS had been labeled from Chinese traditional artworks by hand for the pictures feature map, which was used to train the model. After that, the model was proposed to extract and quantify the data of CTCH.

Second, in the work of chapter 5. The original data of images were optimized and reprocessed through the three models to build by Aesthetic evaluation and improvement method for the dataset of CTCS.

The development method for CTCS that was proposed in Chapter 6 and Chapter 7, it was provided the operation of data to make it to be renewable data that can be updated, transform, use, accumulated, and circulates in this way for the CID method in this dissertation or other related work.

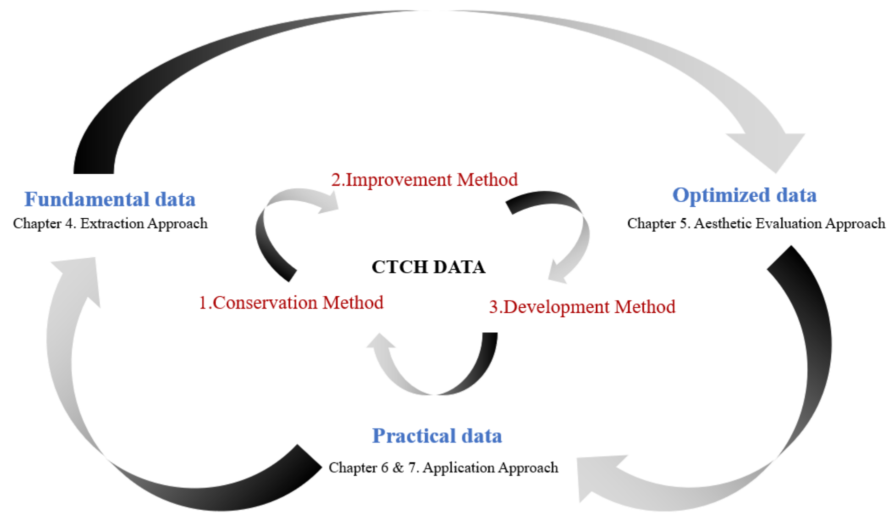


Fig. 3-6 Data Flow

3.3 The Objective and Participant

3.3.1 The Objective

At beginning of the dissertation, multiple aims had been set. First, this research intends to make art and aesthetics conscientization. For this goal, the research literature related to aesthetics, inheritance, had been sorted out through literature review, and a comprehensive method suitable for this study is found, which is to solve the problem of this research through qualitative research and quantitative research combined with interdisciplinary methods.

Secondly, the purpose of this research is to inherit Chinese traditional color culture the objective of this research is to study CTCH with science manner. In the work, the CTAW has been taken as the research object, about 10,000 images of Chinese traditional artworks had been collected from the book, image search engine, and the museum website, the detail as follows:

The Palace Museum of Beijing (https://en.dpm.org.cn/).

National Museum of China (www.chnmuseum.cn/zp/).

The Palace Museum of Taipei (https://digicol.dpm.org.cn/).

Famous Paintings of The Forbidden City (https://minghuaji.dpm.org.cn).

National Art Museum of China (www.namoc.org/en/).

Nanjing Museum (http://www.njmuseum.com/en).

The British Museum (https://www.britishmuseum.org/).

The Fitzwilliam Museum (www.fitzmuseum.cam.ac.uk) etc.

Subsequently, the color scheme was extracted from the images and carried out through the established color extraction method, and after that, the basic database of this research was established.

Thirdly, this dissertation aims to present the methods of digitization inheritance and application that contain conservation, improvement, development for CTCH. For this goal, the illustration of the summary is followed in the section of the procedure.

3.3.2 the Participant

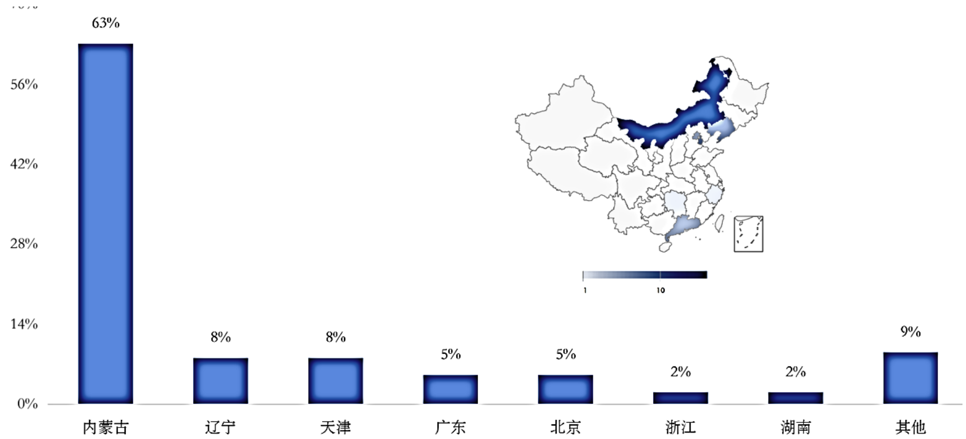


Fig. 3-7 Online Experiment Location Distribution of the Participant

A total of 632 participants participated in the experiment, including 154 offline participants, and 478 online participants which mainly from the Liaoning, Nei Menggu, Hubei, Zhejiang, Guangzhou, and Hebei provinces of China, Online experiment location distribution of the participant is shown in Figure 3-7.

3.4 Procedures

3.4.1 Conservation Method

In Chapter 4, the main purpose is to build up a dataset of CTCS which included various types of Chinese traditional artwork. To achieve the goal, this part proposed the color scheme extraction method for the image of CTCS, and through the method that the basic database of CTCS for the dissertation is classified and quantified, and an extraction website tool for CTCS had been built up.

3.4.2 Improvement Method

In Chapter 5, the Modern Chinese traditional color harmony inheritance approach for the CTCH improvement method is based on the deep learning method. This chapter is mainly an extension and in-depth study for CTCH. The research contained in this chapter is based upon three model architectures such as Lasso regression, NIMA, and W_GAN model architecture, constructing the perceptual quantitative model and an optimization model of CTCS and then proposing the item specific methods and procedures for the CTCH inheritance. This process and results can provide an algorithm model basis for the subsequent interactive research system.

3.4.3 Development Method

This part contains two main works. First, in chapter 6, an interactive website CTCS system had been proposed based on data and workflow acquired from previous work in chapters 4 and 5. In the work process, the high-speed railway as the application environment, the participant can use the interactive system to create the CTCH and makes it more cater with the highly aesthetic scores. Second, in chapter 7, to build up the sensibility relationship with the learning system which can be used to express the CTCS, through the CTAW image, the Tang poetry, and Chinese traditional colors. The system in chapter 7 is mainly through the interactive progressing to help people learn and understand how to use CTCS and the background knowledge of CTCC.

3.5 Data Collection Approaches

Due to the COVID-19 pandemic that collecting data is a very difficult task. For this, according to the development status of the epidemic, two ways of data collection had been adopted, collection online and offline that are to form a mutually complementary model.

3.5.1 Online Collection

This part mainly adopts two ways to carry on the online questionnaire experiment.

First, The Wen Juan website(www.Wenjuan.com), this website can create a customizable questionnaire. Based on the website, this dissertation has created 5 items of online questionnaires and the evaluation experiment, and the experimental result of the comparison questionnaire for chapter 4. The system satisfaction questionnaire is based upon the Likert scale for chapter 6. In chapter 7, Semantic Relationship between sensibility adjective with CTC, Semantic Relationship between CTC and CTP, and Interaction System Satisfaction Survey

Chapter 4, Results Comparison and Evaluation

The Link: https://www.wenjuan.com/s/UZBZJvzcGI/, as shown in Figure 3-8.

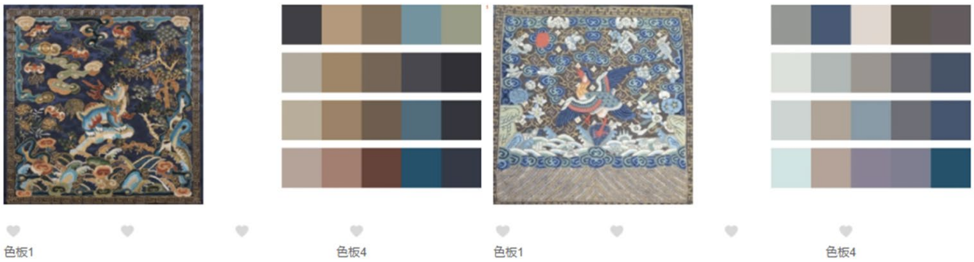


Fig. 3-8 Chapter 4, Results Comparison and Evaluation

Chapter 6, System Satisfaction Survey

The Link: https://www.wenjuan.com/s/UZBZJv6J9DA/, as shown in Figure 3-9.

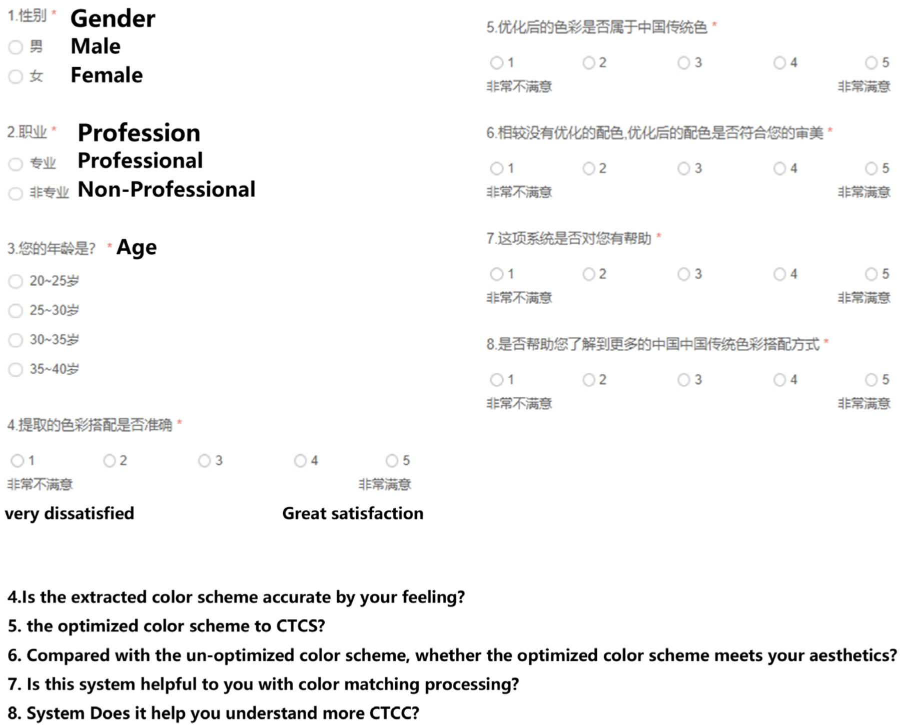


Fig. 3-9 Chapter 6, System Satisfaction Survey

Chapter 7, 1. Semantic Relationship between Chinese traditional color (CTC) and Tang poetry (TP). 2. The interaction system satisfaction survey.

Chapter 7, Semantic Relationship between CTAW and adjective.

The Link: https://www.wenjuan.com/s/ueaQVjB/, as shown in Figure 3-10.

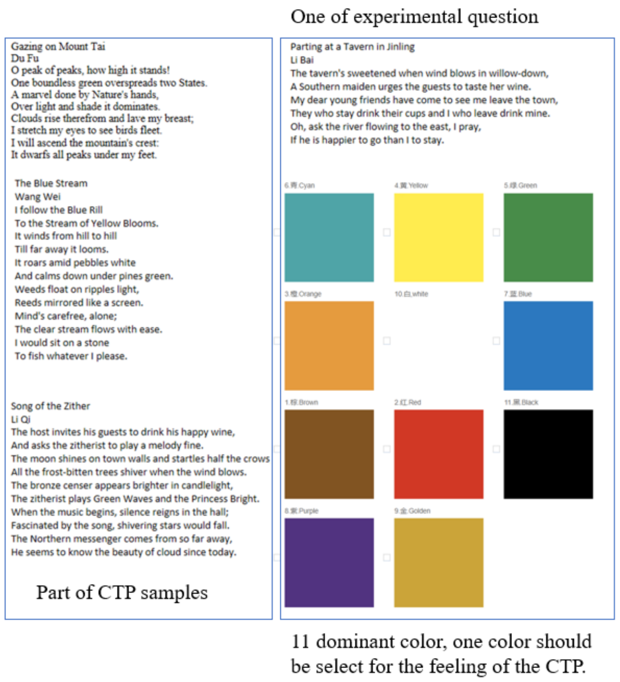


Fig. 3-10 Chapter 7, Semantic Relationship between CTC and TP

Second, two websites had been found for chapter 4, and chapter 6 that can collect data and upload the collected data to the dataset for this research.

Chapter 4, Color Extraction Website

The Link: http://114.55.166.12:23225/color/index.html, as shown in Figure 3-11.

Fig. 3-11 Chapter 4, Color Extraction Website

Chapter 6, High-Speed Railway Interaction Website

The Link: http://114.55.166.12:23225/autocolor/index.html, as shown in Figure 3-12.

Fig. 3-12 Chapter 6, High-Speed Railway Interaction Website

3.5.2 Offline Collection

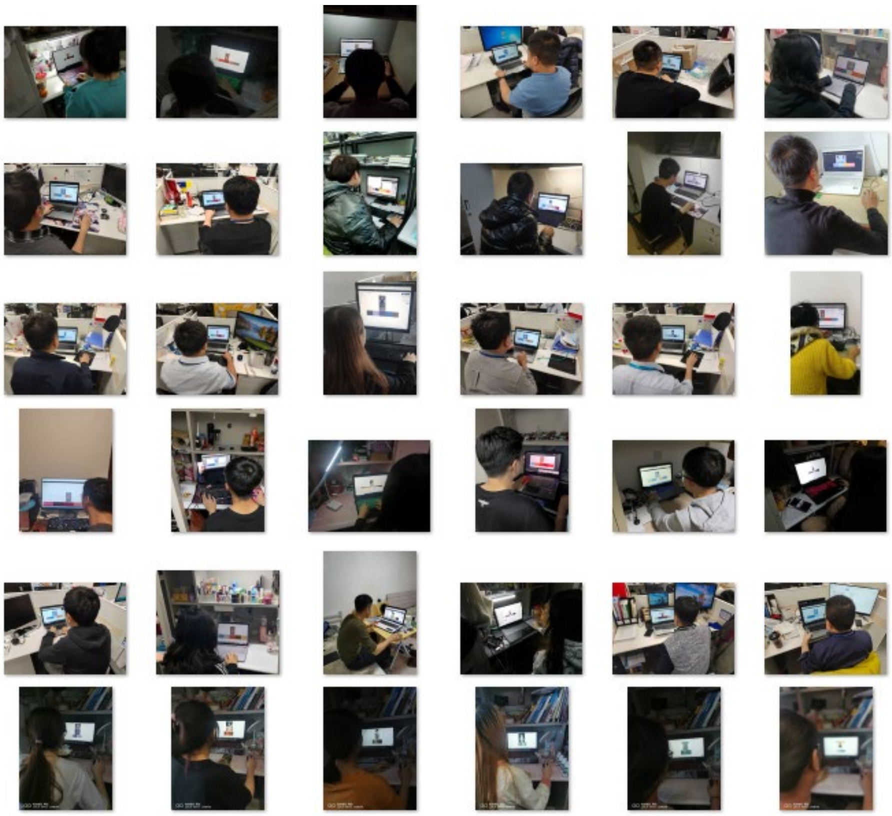


Fig. 3-13 Part of Offline Experiment Photos

This part mainly adopts the form of field visit experiment and exchange dialogue inquiry. For chapter 5, the laptop computer with experimental software has been taken to the school, the corporations, and the hospital to ask for help with the experiment and data collection. For chapter 7, the VR system built in this work that had been taken in mobile hard disk drive to the school to experiment. Part of the experimental photos is shown in Figure 3-13.

CHAPTER 4 An Extraction Approach of Chinese Traditional Scheme Colors Based on Chinese Traditional Artwork

The CTCC and the CTCH are numerous and complicated, and there are lots of differences in various historical stages, due to the massive volume of it that is difficult to digitalization, which is for the conservation aim. To better conserve and inherit CTCC and CTCH, it is essential to follow and combination the modern chromatic science and color standards. In this chapter, a method had been proposed which focused on the extraction of CTCS. Secondly, the results that compare with the existing color extraction methods, proved that the method in this study can obtain more acceptable visual perception from participants. Third, through the extraction method the CTCH database, and website application had been built up.

4.1 Introduction

CTCC and CTCH is long and brand-new topic. Today, it still has a far-reaching impact on contemporary Chinese color culture and Asian color culture. (Louise, 2015). In Chinese traditional philosophical values, the philosophical concepts of Yin-Yang and the Wu-Xing that the five kinds of the element which are the Gold, the Wood, the Water, the Fire, the Earth are the basis and foundation that the construction of all things in the world. (Du & Wang, 2019)，This kind of aesthetic concept has lasted for more than 2500 years in China, and the color combination in the form of five-element is the most commonly used expression of CTCH. In the traditional five elements, five-colors refer to the category of color collocation composed of five. It is usually expressed as 青 (the blue or cyan), 赤 (the red), 黄 (the yellow), 白 (the white) and 黑 (the black) (M. S. Lee et al., 2012). The way of Chinese traditional color matching is not only satisfied with the beauty of human vision but also a unique view of aesthetic cognition influenced by Chinese traditional culture. Unfortunately, there is not an appropriately quantitative digitalization method that concentrates on the characteristic of CTCH and CTCS.

The viewpoint of this research, the first reason is that there are many different color standards for Chinese traditional color system, but the Chinese national traditional color standard only contains 164 colors which is declared in 2015 (GB/T 31430-2015), The color standard of the Chinese traditional color is less than hundreds or thousands of color codes compared with the international color system such as the PANTONE color system, the PCCS color system, and NCS color system, which is far from enough for the research examples of Chinese traditional colors. For example, 625 colors are involved in the chromatogram of 1957, which is the earliest available literature on the expression of Chinese traditional colors. The traditional Color of China, published by Japan in 1986, contains 320 colors. The Chinese Color system, published in 1995, contains 1338 colors. The Chinese traditional Color name and Chroma characteristics, published in 2015, contains 164 colors. Most of these projects try to quantify the accuracy of Chinese traditional color, but up to now, there is still not a relatively perfect color matching system of Chinese traditional color. The reason is that the CTCC and CTCH are numerous and complicated, the span of the artistic style contained in the historical stage is very different, and it is difficult to divide the artistic style characteristics of different periods. In addition, massive historical matters need to be restored and conserved, and the main reason is that none of them can be used as a common standard way of quantification which involved all colors and can provide shared and constantly updated quantitative data.

The second reason is that there is more theoretical research, but less applied research for CTCH. Fortunately, scholars have become aware of made corresponding contributions to this in recent years. The study presented the application of Han Dynasty cultural elements to modern product design by color science (L. Chen et al., 2014). The research is based on the K-Means clustering method the color scheme of Yuexiu dress in Chinese traditional color culture is extracted (Zhe et al., 2019). The method based on the PAD model explores the relationship between CTCS and human perceptual cognition through psychological methods. (Xu, 2020). The study through Pantone Color Guide and ImageJ explores the traditional color matching mode of Yi apparel in Chinese traditional color culture (Ji et al., 2020). The work proposed a color optimization model, and the aesthetic optimization process of CTCS (Shi et al., 2021). The above research provides new ideas for exploring CTCC and CTCH. Therefore, the view in this work had been considered that, for the inheritance and development of Chinese traditional color culture, it is essential to adopt the mixture approach to seek and study the CTCC and CTCH with chromatology with computer graphics and other related disciplines.

Concretely, this work is to seek a manner that could be used to acquisition and extract the composition and component of CTCH. Through the works had carried out two contributions: First, the work had proposed the model focusing on extracting CTCS. Compared with the existing methods, this model can more effectively take the CHCS information from CTAW, and it is an extension as a website color extraction tool for display and use. Second, a quantitative database of CTCS data based on the extraction results of the model is established. In the work process, the database of CTCH mainly includes Chinese traditional apparel, Chinese traditional auspicious pattern, Chinese traditional embroidery fabric, Chinese traditional minority pattern, and makes a preliminary classification based on color relative to each category.

Some results and methods had been compared by literature review. It is found that the color extraction methods or calculation models in the related research can provide an effective solution, but the color extraction results of Chinese traditional artworks are not ideal. In addition, it is worth noting that when evaluating the results of the color scheme, the quality of the reference theme is based on the visual and subjective comparison, which may be affected by cultural and social aspects (Pierce et al., 2003).

4.2 Research Method

Overview

In general, the methods had been proposed in this study include the three aspects of works: 1. Collect and sort out verifiable images of CTAW for classification, and sample data extraction with the Chinese national color standard. 2. The fundamental dataset has been built for training Mask R-CNN. 3. The color extraction website tool that focuses on CTCS had been established.

Primarily, regarding the research objective which is the images of Chinese traditional artwork (CTAW) had been collected and extracted as the foundation. Equally, the Chinese national color standard had been adopted, this procedure ensured the results of CTCS veracity. Subsequently, the images are segmented by Mask R-CNN which is a general framework for object instance segmentation (Kaiming He, 2017). This work is adopted the Mask R-CNN to identify the areas in the image that need to be eliminated. Whereafter, the color scheme is extracted through the K-means from the image region which had been segmented by Mask R-CNN. Additionally, it is difficult to generate the CTCS accurately only by the K-means. This work had adopted W-Gan_gp which has performed better than standard WGAN (Gulrajani, n.d.). The W-Gan_gp can enhance the CTCS which was extracted from the CTAW image by K-means with Mask R-CNN.

4.2.1 Research Sample

a. research object

Primarily, the images of the CTAW had been taken as the object of study, and six image categories were set up according to the types, including Chinese traditional costumes, Chinese traditional auspicious patterns, Chinese traditional embroidery fabrics, Chinese traditional minority patterns, and Chinese Dunhuang patterns, Tangka, etc. the total numbers of 10,000 images are from the official resource which is The Palace Museum of Beijing, National Museum of China, The Palace Museum of Taipei, Famous Paintings of The Forbidden City, National Art Museum of China, Nanjing Museum, The British Museum, The Fitzwilliam Museum, the website link please refers the chapter 3.3.1. And the resolution of each image is higher than 300 dpi. The part of the sample is shown in Figure 4-1.

Fig. 4-1 Part of the Sample

b. National color standard

This work had been according to several Chinese national standards, link as follows, and including:

a. Specification of colors (GB/T 3977-2008).

The link: c.gb688.cn/bzgk/gb/showGb?type=online&hcno=76064E2096BDD1ECB81714EE4328DF4C

b. Uniform color space and color difference formula (GB/T 7921-2008).

The link: c.gb688.cn/bzgk/gb/showGb?type=online&hcno=77970C89C6821735F77687C32FDDBFF6

c. Names and colorimetric characteristics of traditional colors in China (GB/T 31430-2015).

The link: c.gb688.cn/bzgk/gb/showGb?type=online&hcno=6EE6FE2D911C427227830938D027D447

4.2.2 Color Visualized and Standardized

Due to （***Names and colorimetric characteristics of traditional colors in China GB/T 31430-2015)*** which is shown the 164 colors of Chinese traditional color (CTC) by color coordinate with CIE1931 standard. In the CIE1931 standard chromaticity system, the color is expressed by the stimulus value Y and the chromaticity coordinate x_{10}, y_{10}. Therefore, those 164 of CTC can`t be used directly, it needs to be transformed from color coordinate to the LAB or RGB format. And this procedure had according to two kinds of Chinese national standards of color which are the specification of colors standard (GB/T 3977-2008) and uniform color space and color difference formula (GB/T 7921-2008).

The specific steps of color space transformation are shown in Figure 4-2, and as follows: Step 1. transforms CIE 1936 that is the x_{10}, y_{10}, Y of the standard color is converted into the tristimulus value X, Y, Z of the CIE1964, according to the preconditions the D65 which provides the corresponding coordinates for CIE standard lighting in the traditional Chinese color standard (***GB/T 31430-2015***). Step 2. Transform CIE 1936 of the tristimulus value to CIE1964 X, Y, Z. Step 3. transform the CIE 1964 (X, Y, Z) to CIE 1976 (Lab) according to the conditions as the D65. The CTC results of the color coordinate, the LAB, and the RGB are shown in Appendix Table I.

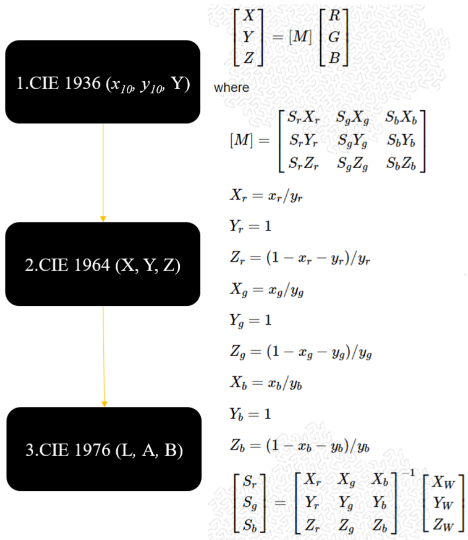


Fig. 4-2 Transform Procedure

4.2.3 Sample of Extraction Data

The work had been done through the color range of Chinese traditional color palette to extract the color scheme of each image which is the construction by Five-color scheme. In the work process, mainly use the Photoshop software version 2021 to extract the images by hand. According to the 164 of CTC data from results of Appendix Table I, the palette in photoshop was established as a standard color palette that was used for extracting the samples. Notably, during the extraction process, the color sample extraction point is set to the average area by 5 x 5 with a middle value of color (the average color value inside the circle radius is 5), the case is shown in Figure 4-3.

The meaning of this is to make sure that the median of the color value relative to the region in the color space is extracted, not a specific point in it. After that, each image extraction data was saved in an excel table, a total of 2000 Five-color schemes of images were extracted.

After discussion with two color experts and two designers, 300 inappropriate color extraction results were excluded which are not suitable for the color expert visual cognitive and professional viewpoint to CTCH. Finally, only 800 images results were regarded as the training data samples to the color extraction model.

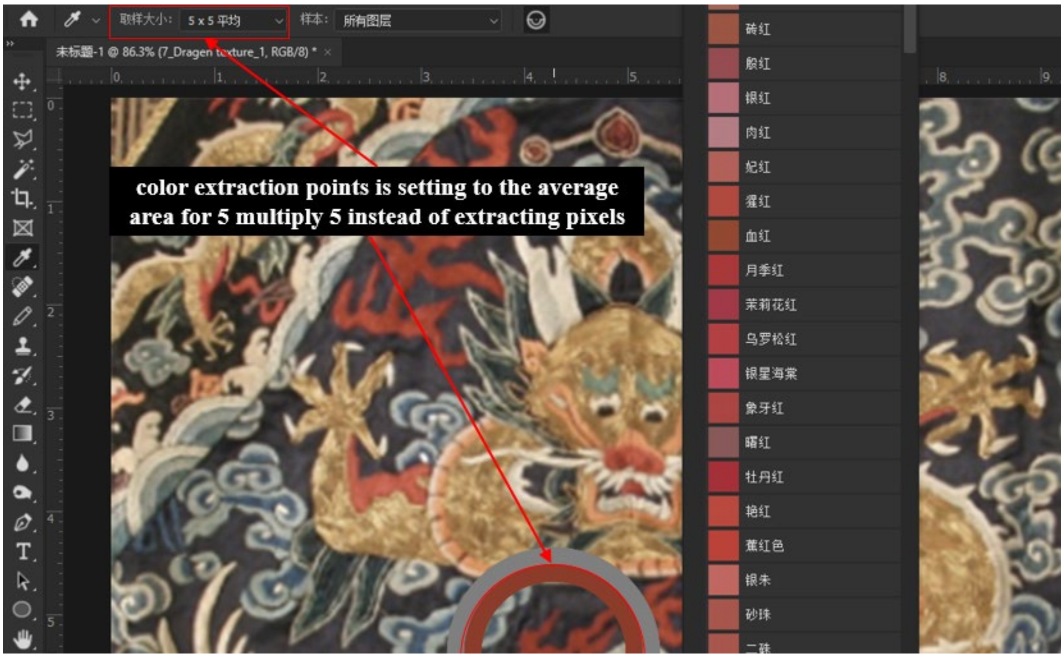


Fig. 4-3 The Sample with Extraction Process

4.3 Color Scheme Extraction

Through the reproduction of the existing color extraction methods, it is found that the color can only be raised for the whole image, and it is difficult to exclude unnecessary areas, which leads to the problem of inaccurate extraction of CTCS. To solve this problem, Mask R-CNN had been used to eliminate unessential areas in the image. Mask R-CNN is a general instance segmentation network (He K, 2017). The network can be divided into two branches, the first branch is the structure of the original Faster R-CNN (Ren S, 2015), which is used for the classification of candidate windows and window coordinate regression, and the second branch is the full convolution network FCN (Long J, 2015), which is used to predict and segment the mask for each region of interest. The loss function of Mask R-CNN is shown in equation (4-1).

$$L = L\_\text{cls} + L\_box + L\_mask \tag{4-1}$$

L_cls is the classification error; L_box is the detection error of the frame; L_mask is the segmentation error. After that image feature annotation, the image data annotated in this work had been imported, and the image was segmented by Mask R-CNN to identify the target areas. This process is shown in equation (4-2).

$$R = M\ (i) \tag{4-2}$$

The R is the binary mask map means the segmentation result of the image after training the model. The M means the trained model for Mask R-CNN. The i means the input images for the model. The R is the mask map corresponding to the two categories that are desired regions and excluded regions. And the work designs a CTCH image enhancement network based on WGAN_gp (Gulrajani, n.d.), and the objective function of the network is shown in equation (4-3).

$$L = \underset{\tilde{x}\sim P_g}{E}[D(\tilde{x})] - \underset{x\sim P_r}{E}[D(x)] + \lambda \underset{\hat{x}\sim P_{\hat{x}}}{E}[(||\nabla_{\hat{x}}D(\hat{x})||_2 - 1)^2] \tag{4-3}$$

$\underset{\tilde{x}\sim P_g}{E}[D(\tilde{x})] - \underset{x\sim P_r}{E}[D(x)]$ is the objective function of W-GAN, $\lambda \underset{\hat{x}\sim P_{\hat{x}}}{E}[(||\nabla_{\hat{x}}D(\hat{x})||_2 - 1)^2]$ is the gradient penalty function used in W-GAN_gp. P_r is the data distribution and P_g is the once again model distribution implicitly by $\tilde{x}$. The D is the set of 1-Lipschitz functions (Gulrajani, n.d.). The x is the expected value. The λ is the hyperparameter.

4.4 Evaluation

4.4.1 Extraction Methods Compare

To verify the effectiveness of the proposed results, this study reproduced and visualized the results of color extraction, included other three methods to compare with the research method in this work. Specifically, the four methods are (MMCQ), (K-means), (Mask-R-CNN, and K-means) and our method included (Mask-R-CNN, K-means, and Wgan_gp). Additionally, this study made a questionnaire through the Wen Juan website, which contains the four-level scale of 100 questions, each corresponding to four options, and each option corresponds to the results of the reproduced sample, as shown in Figure 4-4. The experimental website link is as follows:

https://www.wenjuan.com/s/UZBZJvzcGI/

It should be emphasized that, for the credibility and objectivity of the experiment results, we did not use any words or texts to explain the content of the image, but only asked the experimenters to judge according to their visual senses. Participants need to choose the heart icon in the sequence according to their cognition and feeling as the color scheme which are they think is more suitable with the image. The question is: '*Which scheme is more in line with your visual perception and matches the content of the image*'.

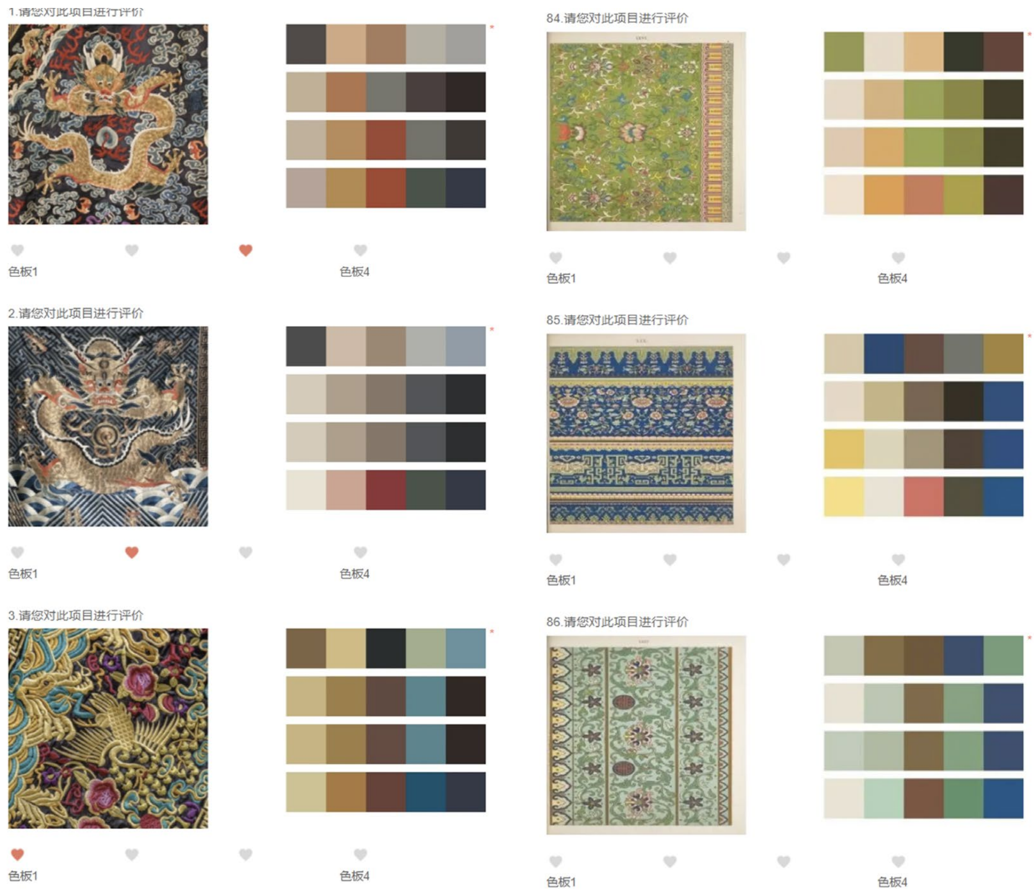
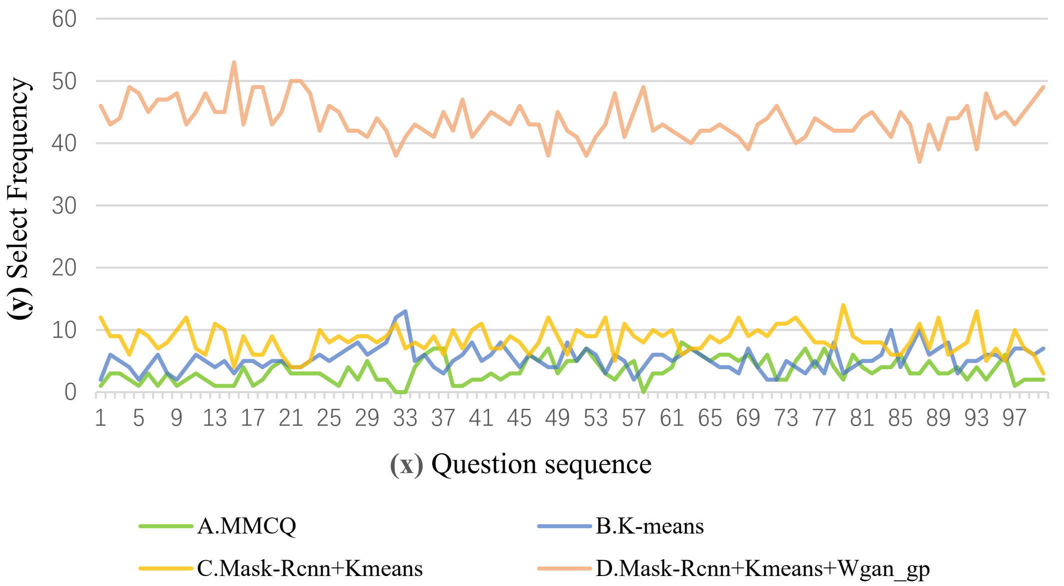


Fig. 4-4 Part of the experimental webpage

In the experiment period, a public questionnaire was distributed through the WeChat platform and Wen Juan platform, and 61 portions were received within three days. Through this result, it can be proved that compared with the other three methods, the method of D (Mask-RCNN+K-menas+Wgan_gp) had a high rate of selection by the participants. The compared results as shown in Chart 4-1.

Chart. 4-1 Extraction Method Compare



Due to no ground truth can be as the comparison target and standard, this study is based upon the human visual perception to compare the results of several research methods and verify which method is better (S. Lin & Hanrahan, 2013b). Through the results of chart 1, it can be seen and proved that the CTHS extracted by the method of D (Mask-RCNN+K-menas+Wgan_gp) has a higher degree of color scheme for human visual perception, and the other three methods also have the well of select frequency rate, but based on the experimental results, the three methods do not have much difference in the dimension of human perception.

4.4.2 Brainwave Test

Due to the basic definition of color harmony is a kind of pleasure feeling when seeing a suitable color scheme that belongs to the aesthetic. The area of the brain will generate mapping feedback when humans feel pleasant (Saha et al., 2015). The pleasant feedback is mainly expressed by Beta (β) and Gamma (γ) of human brain waves (Xing et al., 2019).

The experiment computer parameter that the CPU is I7-9700K 3.6 GHz. The memory type is DDR4 16G 3200MHz, GPU NVIDIA 2080. The VR equipment is HTC VIVE pro, the brain wave testing equipment is LOOXID, as shown in Figure 4-5.

Fig.4-5 The VIVE pro and LOOXID

This part aims to further test the results from the method, whether it accords with the aesthetic cognition of people, this part carries on the brainwave test through the brainwave instrument. In this section, 6 Chinese traditional art images and their color scheme as the samples with great hue differences are selected as experimental subjects. The experimental environment is built on the UNITY platform. Based on the source application provided by LOOXID, the experimental scene can real-time generate the corresponding brainwave data, a case with a sample with brainwave is shown in Figure 4-6.

Fig. 4-6 case with sample with brainwaves

A total of 6 participants took part in the experiment. Each participant was asked to wear a brainwave device and observe that the image was recorded in the experimental video for 20 seconds, and the brainwave data with the highest concentration in the video was intercepted. Based on the overall amplitude and trend of the data, the analysis of the data results showed that the participant's beta-wave and gamma-wave were significantly activated. For more details of the six cases with samples, please refer to appendix II. Based upon the test data, the color schemes produced by this method also can produce pleasant feedback to the participants, which proves that the color scheme results extraction method proposed by this study is also satisfied with aesthetic cognition.

4.5 Result

4.5.1 Image Segmentation Result

In this part, it is vital to manually label the original image as the preparatory work for training data. And a total of 1172 images are labeled as the training data. The red mask is the desired region and the cyan mask is the excluded region. As the presentation sample, we show part of the labeling results that are shown in Figure 4-7.

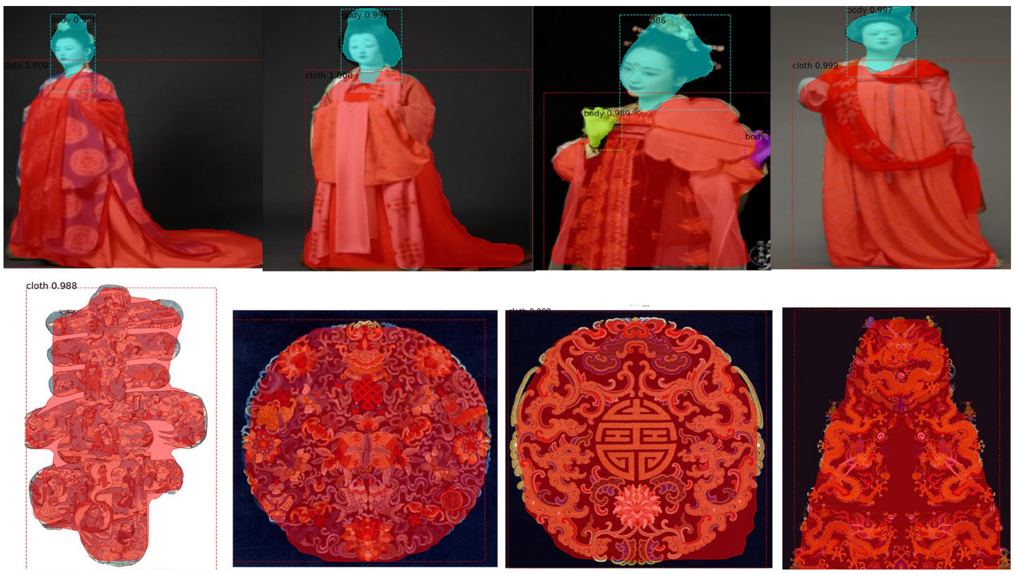


Fig. 4-7 Image segmentation results

4.5.2 Image Extraction Result

In this part, to show the results of this study more intuitively, the four methods of result that are the (MMCQ) as the M, (K-means) as the K, (Mask-Rcnn and K-means) as the MR, and our method included (Mask-R-CNN, K-means, and Wgan_gp) as the O, the result is shown in Figure 4-8.

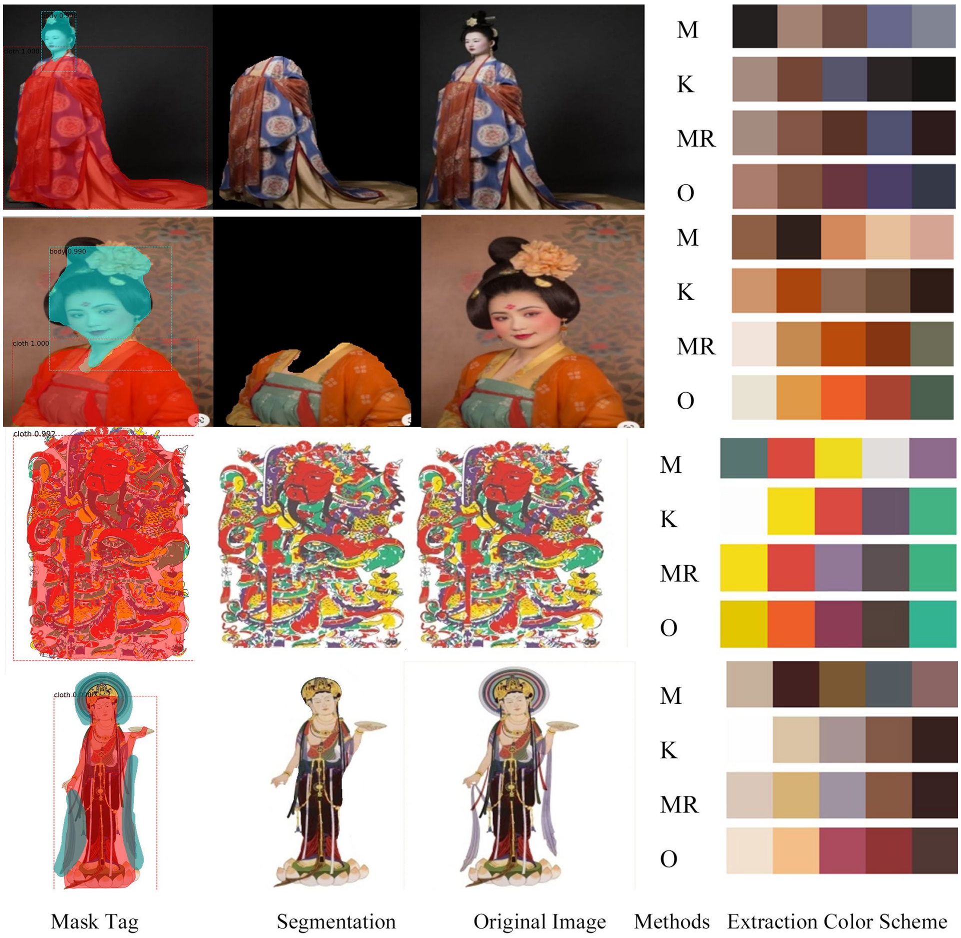


Fig. 4-8 The Results

4.5.3 CTCS Extraction Web Tool

Based on the proposed extraction method, this study constructs a web application tool for Chinese traditional color schemes. This web color extraction tool only needs two simple steps to extract colors effectively. First, the user needs to upload the prepared image with the upload button. Second, click the generation button to display the color scheme of the image on the web page, the webpage as shown in Figure 4-9. Additionally, it can be used to increase the data range through the process of accumulating data continuously for the next period of work.

The website link is as follows:

http://114.55.166.12:23225/color/index.html

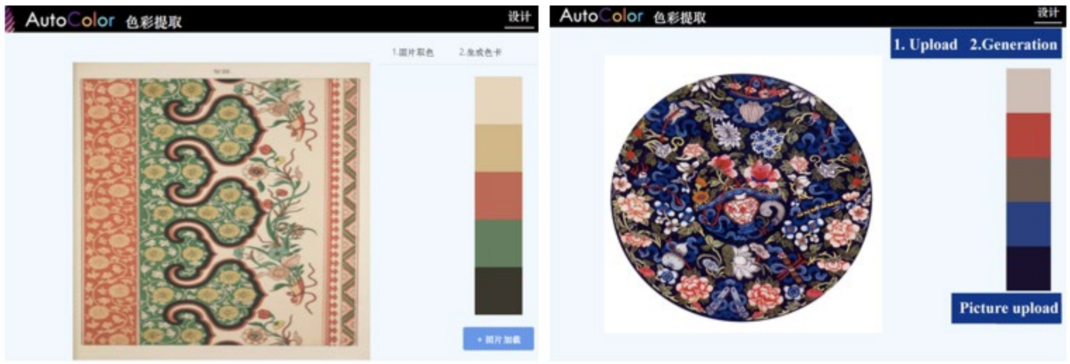


Fig. 4-9 Color Scheme Extraction Webpage

4.6 Discussion and Limitation

The core purpose of this study is to explore the composition of CTCH and CTCS. The color extraction method and CTCS quantitative database had been established. Based upon the data, the evaluation and comparison results show that compared with the other three methods, the method of this study had a high rate of selection by the experiment participants. From the brainwave test, the color scheme results from the extraction method proposed by this study are also satisfied with aesthetic cognition. And the quantitative database of CTCS established in this study can provide the basis for related research in the future.

However, CTCC and CTCH are too complex and tedious, and it needs to be sorted out step by step and subdivided into various categories, due to the enormous volume of the CTAW it is. At the same time, the major limitation of this study is the amount of data used for training. To achieve high color extraction accuracy, two larger training data sets are needed, which is also a common problem encountered by all color extraction algorithms at present.

4.7 Conclusion and Future Work

The motivation of this study is to inherit Chinese traditional color culture. By summarizing the past color improvement methods, it is concluded that the framework of the method which is proposed by this work, is more suitable for establishing the color improvement model of this study. In a summary, this study mainly completed four tasks: 1. An example is introduced to the segmented network to separate the unessential content from the background of images. 2. A novel algorithm model of the image color scheme extraction method for the CTCC and CTCH is specially designed. The results show that the more accurate than the previous methods in our method for Chinese traditional artwork, and a web application of color extraction tool is established based on the color extraction model. 3. The color standard index is added to this study, which is more targeted and accurate than the results of previous studies. 4. Through the color improvement method in the study, a basic quantitative database of Chinese traditional color-matching data is constructed. In the summary, this integrated process absorbs the advantages of the three models, improves the efficiency compared with using each model alone and preliminarily solves the comprehensive problem of generation and optimization of Chinese traditional color schemes.

For future work, it will consider collecting more verifiable image samples from various historical periods in China and further classifying each category into subcategories. In addition, it is worth explaining and paying attention that, the basic work of Chinese traditional color in pigment material and qualitative analysis needs to be further improved. This item explores the composition of CTCH and CTCS, but the accuracy of color value and the range of sample data need to be further supplemented and calibrated. In future research, it will be supplemented and improved according to the relevant research of Chinese traditional color.

CHAPTER 5 Contemporary Chinese Traditional Color Harmony Aesthetic Renew Based on the Deep Learning Approach

There have differences in aesthetic concepts, ideas, and aesthetic attitudes between the East and the West. Regards CTCH, how to optimize in an objective way to cater to the development of the epoch. It is essential to satisfy the demands of the aesthetic satisfaction of modern people. For this goal, in this study, a new approach had been proposed that could generate CTCS and optimize CTCH. Based on the visual perception experiment, the work had been obtained the visual perception score of CTAW. Usage the participant's sensation scores data as an input baseline, and COLOUR LOVERS website data as the general aesthetic scores, to seek a general visual perception rule which could cater to the aesthetics requirement of modern people. This chapter proposes a systematic process of CTCS to seek an approach to inherit and develop for CTCC and CTCH.

5.1 Introduction

Human beings continue to pursue beauty, exploring and studying beauty in various ways in different periods. They try to give new dimensions and definitions to beauty by different means and ways, but these definitions are full of opposites and unity. Western aesthetics has explored beauty through philosophical speculation and mathematical formulas since ancient Greece. On the other hand, oriental aesthetics pursues the natural beauty of the unity of man and nature from the CTCC. The study of artistic use of color based on sensory cognition has a long item. Early color studies originated from the analysis of visual perception. Although the study of color has been in the stage of simple empirical cognition for the long term, people have their understanding and treatment of color in the context of both Eastern and Western cultures.

From the Spring and Autumn and warring States period, the Chinese ancients established a set of Five-colors theory, that on the impact of the five elements theory. Although this theory is only an application approach of the concept of Yin-Yang and Five-elements in the chromatic work or an isomorphic paradigm in color cognition, it is a significant concept of Chinese philosophy that emphasizes the balanced way via the white-black color. This method of isomorphism between color and philosophical concepts, but has been affecting the color aesthetic emotion of the Chinese people. The theory of the birth of the Five-elements is the basic model for the Chinese ancients to explain many natural phenomena. The composition of the five kinds of primary colors in the five-color theory is the same as the Five-elements and other theories.

But as the proverb says, every coin has two sides, and CTCC and CTCH is no exception, is has both advantage and disadvantage. With the development of society and the satisfaction of basic matters, people begin to pursue the pleasure of the spiritual dimension. Whether the traditional aesthetic way is still suitable for the contemporary society and people's aesthetic needs? As stated in Maslow's theory, the demand of humans is divided into the satisfaction of matter and spirit.

Confliction of aesthetic view and concept, the theory of color harmony in the 19th century, the large number of color scheme relations which are considered to have no harmonious relationship have been enumerated, and the color combinations with intermediate color differences are called unfeatured color combinations. The color scheme of the yellow and the green, the blue, and the green are called disharmonious lightness relations. The color scheme relationship with harmonious nature should be similar to harmonic and contrastive harmonic. (Nemcsics, 2009a).The combination of red and yellow, green and yellow is the most barren color matching relationship (Fang et al., 2017).

On the other hand, two kinds of color scheme relationships can create harmony color scheme. First, the hue of color scheme with a specific angle, as the 15°, 45°, 90°, 180° that angle in the color wheel is suitable to form a harmonious color scheme, as shown in Figure 5-1. Second, the color scheme with a small difference in lightness with colors, this way also can struct the harmonious sensation (Primož Weingerl & Javoršek, 2018). On the contrary, the color

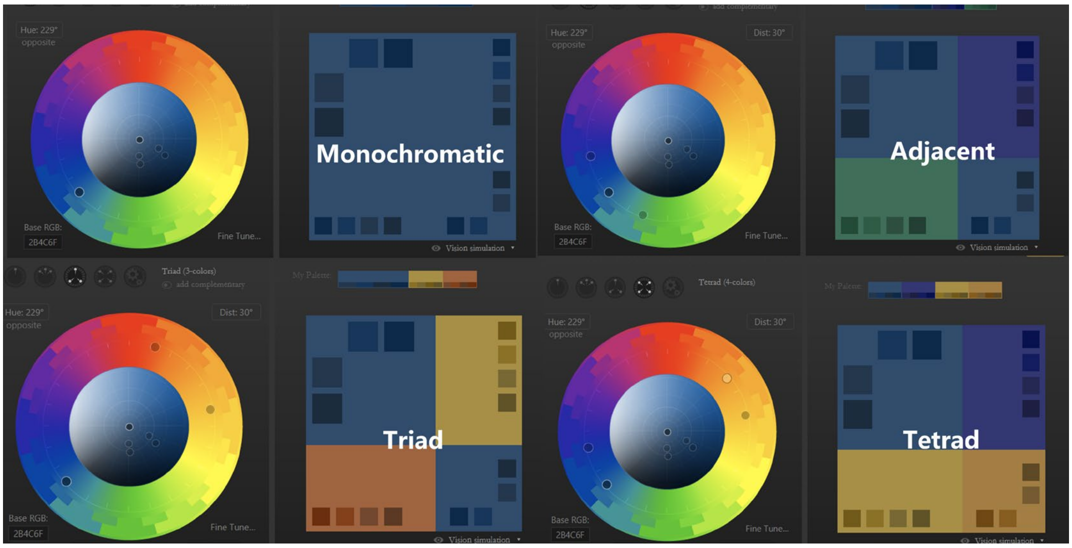


Fig. 5-1 Harmonious Collocation

scheme constructed by adjacent methods in the hue plate will produce poor visual effects. Such as red and yellow, red, and purple, scarlet red and green, yellow, crimson-purple, yellow-orange, and turquoise, these colors are matched in ways that do not have the harmony meaning in aesthetic view of western early 20 century.

Nevertheless, the color scheme methods used in Chinese traditional artworks are the collocation of bright colors such as red, green, and purple with yellow, and the combination of yellow with blue and green. Among them, the combination of red and yellow is the color scheme that often appears in Chinese traditional artworks, and these color matching methods are criticized by western scholars. Simultaneously, in the Japanese traditional color scheme, the YAMABUKI collocation which is the combination of yellow and green, and the collocation of purple and green, some cases are shown in Figure 5-2. These color scheme relationships are all intermediate color collocation relations which is belong to color harmony (M. S. Lee et al., 2012). The cognition of this non-harmonious color relationship has not changed in essence until the 20th century, which shows that the way of color collocation and aesthetic tendency between the East and the West have their uniqueness. Accordingly, in the view of this chapter think that traditional color culture is based on ancient aesthetic concepts and traditional cultural customs, traditional color culture should meet the needs of the times and modern aesthetic cognition.

Fig. 5-2 Traditional Painting Cases

Meanwhile, culture as a tacit phenomenon will be concealed by universal conclusions drawn from explicit knowledge, which should be studied based on both qualitative and quantitative research approaches (Suppiah & Sandhu, 2011). On the other hand, human is the main body of spreading and inheriting culture which is influenced by a variety of subjective and objective factors, and aesthetic emotions depend on visual features (Pierce et al., 2003).

Due to the complexity of the process, this can't be done overnight (Ishai et al., 2007). Therefore, this research aims to explore the general laws between CTCC and human aesthetic perception, and three research questions were asked in this research. Q1, how do modern humans perceive the color scheme that is considered to belong to the aesthetics or harmony of the CTCC? Q2, how to objectively assess the esthetic perception level or score of the CTCS. Q3, how CTCS can be optimized can make it satisfied with the aesthetic perception of modern humans.

In this work, the Chinese traditional artworks were regard the sample and color scheme as the object. Secondly, the visual characteristics scores of CTCS were obtained from 110 participants, that experimenters had been asked to evaluate samples of the color scheme, that through subjective aesthetic perception way to acquire the score of CTCS. After the visual experiments, mathematical modeling was conducted to explore the relationship between the visual perception of modern humans and the characteristics of CTCS. Thirdly, an optimization process of the CTCS has been established with data analysis, comparison, and evaluation. This chapter aims to seek a way to generate the CTCS and optimize the CTCH that could make them more carter with the aesthetic of contemporary humans.

5.2 Research Method

Overview

Several works had been compared, the method of Lasso regression model has better performance for color scheme extraction, but from the results of reproduction that the image themes extracted by the original Lasso regression model are not suitable for CTHS, due to color scheme by original Lasso regression model has unsuitable color by the view of two colors experts and two designers, please refer the detail with the red box in results in Figure 5-3, and it not carter with cognizing for participants. In the view of this work, this is mainly because the candidate colors in the Lasso regression model are extracted by K-means, and the mean value is inevitably used in the color selection process through K-means extraction, outliers or noise data will have a great impact on the means.

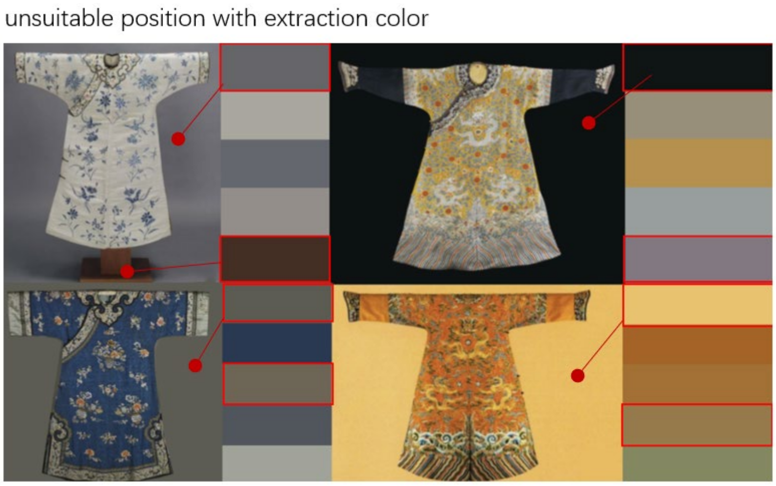


Fig. 5-3 Results of Reproduction

5.2.1 Research Sample Section

The Chinese traditional artworks are the research sample. First, the work input extraction data from chapter 4 retained the Lasso regression model. Due to the large amount range of Chinese traditional artworks, according to the literature and expert suggestions, apparel was regarded as the important element and objective of the traditional culture (L. Chen et al., 2014). Consequently, the apparel was selected as the experimental sample for the beginning of the work.

The work took the types of apparel in Chinese traditional artwork as the sample objects for this research experiment. Besides, considering that the participants would be excessively visually fatigued in the experiment which would affect the result, we invited the experimenter to select traditional Chinese apparel which is the most they like. Finally, based on the comment of 5 color experts that 50 images are selected as the experimental sample from traditional Chinese apparel which is the suitable range for the experiment. The hue of each image is quite different.

5.2.2 Research Subject

In this study, 110 Chinese adults who participated had been invited. Relevant studies have shown that human perception of color is the most acute between the ages of 20 and 30 (Nemcsics, 2009b). The average age of the participants is 25 years old. According to the occupation, 41 students, 10 teachers, and 10 staff doctors. They come from school, company, and hospital in China, including 41 experimenters with professional design experience backgrounds, 59 non-design professional experimenters, and 10 experts. Before the experiment, each participant had been confirmed no issue with color-blindness using the Ishihara Color Vision Test.

5.2.3 Research Mode Architecture

To systematically solve the three sub-problems set up in the research and achieve the major goal. An image color extract model had been proposed which focused on the CTCS. In the work, three research models had been used to build the model architecture, as shown in Figure 5-4(A), which was the Lasso Regression Model (S. Lin & Hanrahan, 2013a), the Neural Image Assessment (NIMA) model (Gulrajani, n.d.), as shown in Figure 5-4(B), and the Wasserstein GAN gradient penalty (WGAN-GP) model (Gulrajani, n.d.) as shown in Figure 5-4(C).

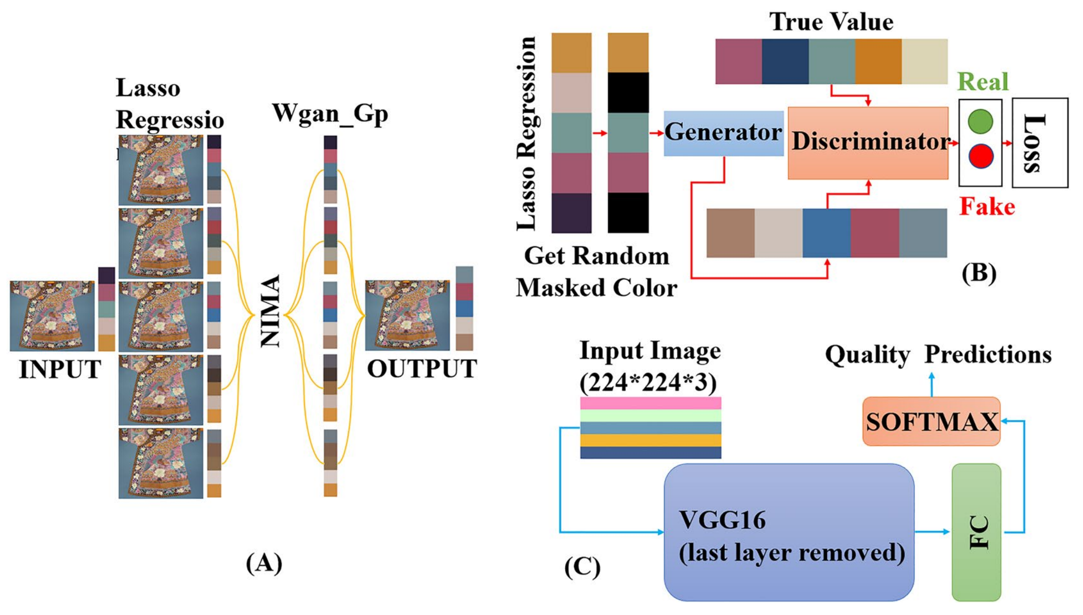


Fig. 5-4 Architecture

In the work process. the visual aesthetic perception relationship between Chinese aesthetic perception and the CTCS. The collected experimental data as input data for the NIMA model that got from chapter 4, and collected 8,743 five-color palettes with ratings on the COLOUR LOVERS website (http://www.colourlovers.com) as the reference data for general aesthetic evaluation, the data of participants and COLOUR LOVERS are shown in Figure 5-9. For Q3, that need to cater with two prerequisites, the one is how to optimize the color scheme that belongs to the category of traditional Chinese colors and the other that cater with the universal aesthetic characteristics, therefore the input image data through the WGAN-GP model as the last process and generate the sample which can satisfy the aesthetic characteristics of the color scheme.

5.3 Research Process

5.3.1 Aesthetics Perception and Color Scheme Extraction

For Q1, firstly we experimented with the aesthetic perception characteristics of modern people. Before the experiment, the work had been prepared a process description for the participants. Each participant was asked to evaluate the scheme of five-color combination information from each one of 50 apparel images. Aesthetic cognitive behavior requires a process of cognition and transformation (Nemcsics, 2012),(Nemcsics, 2009a),(Nemcsics & Takács, 2013),(M. S. Lee et al., 2012). In the experiment processing, we have not set a deadline for obtaining relatively precise experimental results. Some participant has used their computer, but the resolution ratio of the monitors is the Full HD (1920x1080, 16:9). To ensure consistency and precision of color information in each image. All the monitors had been color corrected by the DATACOLOR Spider which is the screen color calibration instrument, and the temperature of the monitor is 6500k which is the common temperature for setting. The participants were asked to give the score with each image on a 5-point scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), which is the scoring scale of the COLOUR LOVER website five-point standard. The vertical viewing angle between the monitor and the observer was set at 90°, and the horizontal viewing angle can`t be over 15° that based on the middle of the screen, due to some monitor display performance is not full angle, if the view range will change the display colors. The distance of the observer with the screen was set from 1.5 meters to 2 meters which is the suitable distance.

To establish the relationship between modern people's aesthetic perception and Chinese traditional color scheme, The work had been calculated 1,000 color matching features from the six features of the image such as salience, pixel coverage, segmentation, color diversity, color purity, and clustering statistics, and calculate the scored the traditional Chinese color scheme, some of the features samples are shown in Figure 5-5.

The main steps are as follows:

(1). 40 colors are extracted from the original image by K-means as candidate colors of the image that have a similar consistency learned from the Turk-extracted method to calculate the initial theme scheme score by using equation 5-1. (S. Lin & Hanrahan, 2013b).

$$score(p) = 1 - \frac{1}{|H|}\sum_{h\in H}\frac{dist(p,h)}{max\,Dist} \quad (5\text{–}1)$$

Where p is one of the themes` color scheme; *H* is the set of topics selected by the expert which mentioned in chapter 4; *dist (p, h)* represents the distance between p and *h*; max *Dist* is the maximum possible distance between the two schemes (S. Lin & Hanrahan, 2013b).

(2). By using the Lasso regression model in equation 5-2, the work can be able to generate color schemes according to the score get from equation 5-1 and the steps go as starting with the first color of the initial theme swatch, replace with the color in the candidate color, and repeat this operation until the replacement of the first color in the initial theme swatch can no longer increase the score of the initial theme scheme. Repeat the same procedure for the second to the fifth color of the initial theme. scheme.

$$\min_{w,b}\sum_i\left(w^T f_i + b - score(p_i)\right)^2 + \lambda\|w\|_1 \quad (5\text{–}2)$$

Where i represents 1 to1000 different topics, w^T is the weight vector, f_i is the eigenvector, b is the bias term, p_i represents the theme score and λ represent the validation ratio constant (Primo Weingerl, 2020). Finally, the theme color schemes obtained are shown in Figure 5-5.

Fig. 5-5 Visualization in Procedure

5.3.2 Assessment of the Color Scheme

To objectively evaluate the color scheme samples extracted from the input image of traditional Chinese artworks, the work used the NIMA model (Talebi & Milanfar, 2018). After data training, the NIMA model can show the score closer to the human perception level of the image. The loss function used in this model is EMD, as shown in Equation (5-3).

$$EMD(p,\hat{p}) = \left(\frac{1}{N}\sum_{k=1}^{N} |CDF_p(k) - CDF_{\hat{p}}(k)|^r\right)^{1/r} \quad (5\text{-}3)$$

p is the user's rating distribution of the picture; $\hat{p}$ is the user's rating distribution of the picture predicted by the NIMA model; $EMD(p,\hat{p})$ indicates the minimum average distance required to move when the movement is completed; $CDF_p(k)$ is the cumulative distribution function, N is the ordered classes of distance. r is the parameter of gradient descent (Talebi & Milanfar, 2018). VGG16 is used as the baseline of the NIMA model.

The function of fully connected to the NIMA network is to classify the properties extracted from the input image. The function of SoftMax is to convert the results of the forward propagation of the neural network to its corresponding probability distribution. The network input is a five-color palette, and the output is the palette's score distribution, and the palette score is calculated according to equation (5-4).

The architecture of the NIMA network is shown in Figure 5-6. Subsequently, 11,000 five-color palettes with scores were collected on the COLOUR LOVERS website as the general aesthetic evaluation reference data, and the NIMA scoring model was retrained which trained with 8,743 pieces of data from the COLOUR LOVERS website.

$$u = \sum_{i=1}^{N} s_i \times p_{s_i} \tag{5-4}$$

u means the score of the picture; s_i indicates the score with $s_1 \leq s_i \leq s_N$, $s_1 = 1$, $s_N = 5$; p_{s_i} indicates the empirical probability of the score.

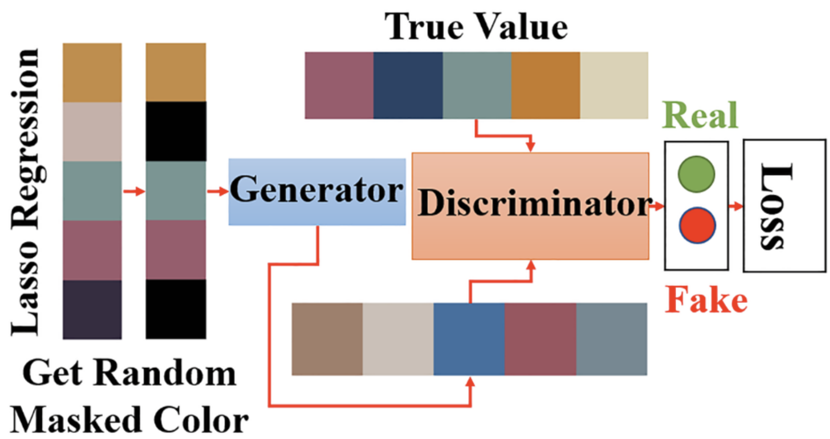


Fig. 5-6 The Architecture of The NIMA Network

5.3.3 Color Scheme Optimization

For Q3, the work had been used WGAN-GP to enhance the results of the Lasso regression model and optimize the color scheme extracted from the image. Based on WGAN-GP, the work designed the image color scheme enhancement network shown in Figure 5-7, and the objective function of the network is shown in Equation (5-5).

$$L= \underset{\tilde{x}\sim P_g}{E}[D(\tilde{x})] - \underset{x\sim P_r}{E}[D(x)] + \lambda \underset{\hat{x}\sim P_{\hat{x}}}{E}[(||\nabla_{\hat{x}}D(\hat{x})||_2 - 1)^2] \quad (5\text{–}5)$$

$\underset{\tilde{x}\sim P_g}{E}[D(\tilde{x})] - \underset{x\sim P_r}{E}[D(x)]$ is the objective function of W-GAN, $\lambda \underset{\hat{x}\sim P_{\hat{x}}}{E}[(||\nabla_{\hat{x}}D(\hat{x})||_2 - 1)^2]$ is the gradient penalty function used in W-GAN_GP. P_r is the data distribution and P_g is the once again model distribution implicitly by $\tilde{x}$. The D is the set of 1-Lipschitz functions (Gulrajani, n.d.).

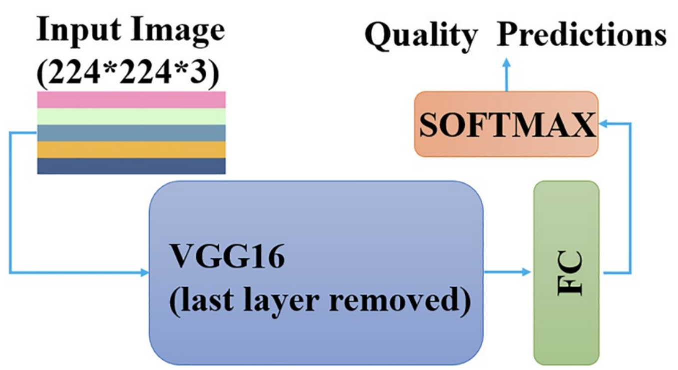


Fig. 5-7 Color Scheme Enhancement Network

According to the color scheme samples obtained in the visual perception experiment data, this is used as the training data of WGAN-GP. For each color scheme sample input to WGAN-GP, the network can generate 31 different color scheme samples (Talebi & Milanfar, 2018). To obtain the best color scheme result, the NIMA model trained in section 5.4.2 is used to evaluate and score the 31 color palettes generated by the network, and select the color combination with the highest score as the resulting output of the image.

5.4 Result and Evaluation

5.4.1 Result of Aesthetics Perception and Color Extraction

Through the train the lasso regression model again with the data from chapter 4, some apparel images from the data source had been used for testing the retrained model. In this section, 9 images with obvious hue differences are randomly selected as display samples. The test results are shown in Figures 5-8 (A, B, C, D, E, F, G, H, I). The two kinds of pictures from the retraining result and the original result from chapter 4 had been printed as the verbal

Fig. 5-8 The Test Results

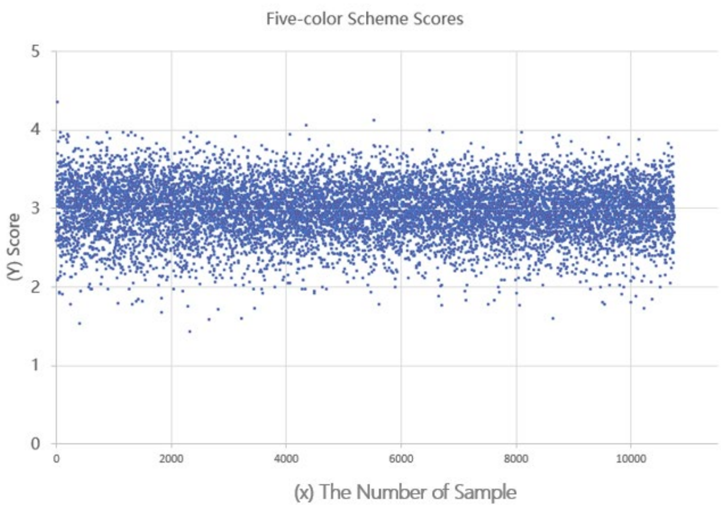


Fig. 5-9 Five-Color Scheme Scores

question samples. From the verbal answer, most people can`t recognition and distinguish which results are better.

5.4.2 Result of Color Scheme Evaluation

To verify the accuracy of the model, from the five-color scheme score, based on the five-color scheme score which is shown in Figure 5-9. And the average user score is set to 2.95 points as the threshold value, as shown in Figure 5-11, while we feed a series of high score color schemes to model and the predicted score was located at a high score range which means true positive (TP) (88) if the predicted score located in a low score range which means true negative (TN) (257). At the second time, we feed a series of low score color schemes to our model and it predicted them in a low score range which represents false negative (92), if it predicted them in a high score range which represents false positive (88). As the result, we can get the accuracy 75.9% by (TP+TN) divided (Total number of data). And the predicted distribution of scores from the NIMA model formed on user data is very close to the actual distribution of scores, as shown in Figure 5-10.

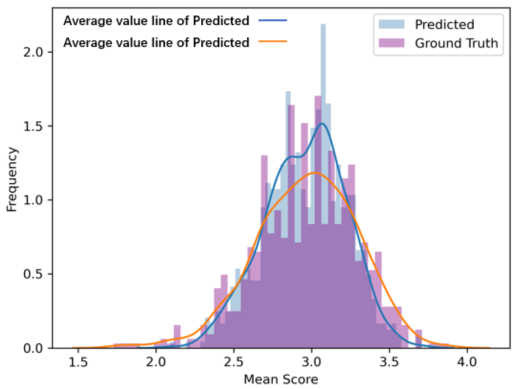


Fig. 5-10 Predictive Score Distribution of the NIMA Model

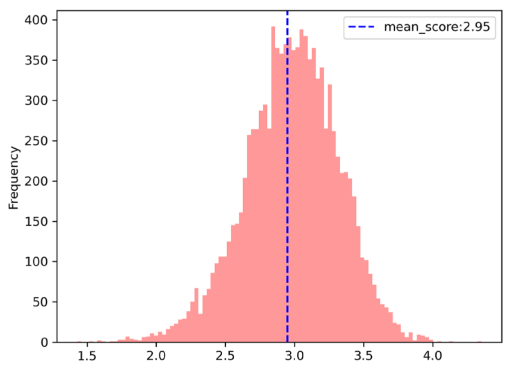


Fig.5-11 Color Scheme Score

5.4.3 Result of Optimizing the Color Scheme.

We compare the image theme score extracted by the Lasso regression model with that screened by the WGAN_GP optimized NIMA model. The results show that 99 of the 100 test images have a higher score after optimization than before. At the same time, we also draw a histogram of the score distribution, as shown in Figure 5-12. From the histogram of the score distribution, it can be seen that color schemes screened by the WGAN_GP optimized NIMA model are more recognized by people which have higher scores. Among them, the picture is the color lifting result of WGAN_GP optimized NIMA model screening of the image of a_w, b_w, c_w, d_w, e_w, f_w, g_w, g_w, i_w, as shown in Figure 5-13. Table I shows the comparison of the scores of the pictures before and after optimization.

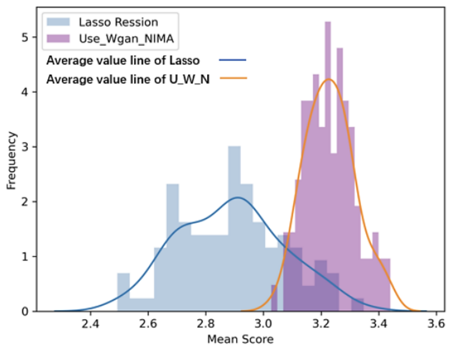


Fig. 5-12 The Histograms of the Two Score Distributions

TABLE I

	Before Optimization	After Optimization
A	3.139	3.262
B	2.930	3.391
C	3.189	3.280
D	3.055	3.253
E	2.926	3.257
F	3.238	3.239
G	3.626	3.134
H	2.657	3.391
I	2.970	3.288

Fig. 5-13 After Optimization Results

5.5 Discussion and Conclusion

Due to the long history of China, the research sample has a large span of Chinese history, and the styles of Chinese apparel in different periods have great differences. Although they have general significance, they lack pertinence. Therefore, in the follow-up research, it is vital to narrow the historical scope and specific categories of the research objects to present the aesthetic value contained in the traditional Chinese color system, and to meet the aesthetic needs of the modern people from the CTCC. On the other hand, in the research process, due to the complexity of the process of acquiring human aesthetic perception, only 50 images were selected as experimental samples in the experiment. In future work, the procedure will be improved by an interaction process to acquire data. To seek the general laws between CTCS and modern people's aesthetic perception, we combed the connotation color scheme of CTCC. And based on the aesthetic perception of the user experimental data, combined with three models to establish a CTCS research process in line with the modern human aesthetic perception generally. Through comparative experiments, we have verified the effectiveness of this research.

CHAPTER 6 An Interaction Web-Application of Chinese Traditional Color Harmony: The Case of High-Speed Railway

6.1 Introduction

6.2 Research Method

6.3 System Overview

6.4 Experiment

6.5 Evaluation

6.6 Results

6.7 Discussion and Limitation

6.8 Conclusion

The construction and development of HSR in recent years have attracted the attention of the world, but the localization and humanistic design of HSR are lacking. To cater to the development of the times and the needs of society, the color scheme concept of HSR needs to have national and contemporary cultural connotations. In this chapter, the work is based on the core concept of CTCC and proposed a website interactive color scheme tool for HSR oriented CTCH. The evaluation of experimental results and user experiments show that the interactive system can effectively generate, optimizing and obtain the harmonious and reasonable relationship of CTCS and visual effect inside HSR. This research explores the localized design concept of HSR, expands the application scope of CTCS, reduces the dependence of color scheme design non-professional knowledge, and provides an effective method for inheriting Chinese traditional color culture.

6.1 Introduction

In 2018, the total operating mileage of HSR had been beyond 29,000 kilometers, and the history of HSR operation exceeded two-thirds of the history of high-speed rail trains in the world, making it the country with the longest operating mileage and the highest HSR network density in the world. The train is a mobile living space. While bringing convenience to people, it also provides a unique experience process. The internal space design of the HSR is not only a design for physical space but also a process of creating an emotional experience. The comfort of passengers during travel does not only come from totally physical satisfaction, but also includes the experience of comfort, happiness, efficiency, and convenience during the ride.

An appropriate color scheme of the interior environment will improve the experience of people's activities in the surrounding conditions. Maslow believes that the process of human needs is a process of continuous development from low to high, from material to related religion or the spiritual. When people are in an environment with a suitable surrounding condition, the feeling of happiness, joviality, satisfaction, physical strength, intelligence, and even spirit can reach a certain level, they can have a good feeling in their consciousness and feel comfortable (Gawel, 1997). As a means of transportation, the design focus of the train is consistent on the research fields of ergonomics such as improving efficiency, increasing safety, and improving ride comfort, although the environment inside the HSR exists in a material form and affects the psychology, emotion, and aesthetics of the passengers. But the aesthetic design of human emotions, such as environmental beauty, has always been placed in a secondary position. With the improvement of living standards, consumers' demand for HSR has changed from simply carrying the needs of transportation to more complex emotional needs. Therefore, it is essential to gradually improve the HSR surrounding condition that meets the physical and mental comfort of the people.

HSR is an important carrier for carrying and disseminating culture. The perceptual factors of color play a vital role in creating an overall environmental impression and shaping a special brand image, which is related to atmosphere or style. Related research has elaborated on the interior color design of HSR. Xue-Lei et al. conducted a related study on HSR seats and colors through the gray correlation analysis method(Lei & Xiao, 2019). Xu Xiao-Fei et. proposed an HSR interior color design method with a natural color system(Lei & Xiao, 2019). Liang-Kui et. put forward a new aesthetic design concept for HSR interior matching based on the analysis of regional cultural characteristic elements (Liang-kui et al., 2016). ZHI et. conducted experimental research on the color and pattern of the train seat mask and put forward design suggestions (L. K. Jiang et al., 2011). However, there are still many imperfections which are lacking the national culture in the relevant design of China's HSR. For this research, we think how to use and recreate traditional and national culture is one of the most important aspects for it, because the traditional culture is the resource for the future, and national culture is the mark and brand of civilization of the world.

To the summary, the problem of the traditional and national color scheme in the interior environment of HSR is mainly due to three factors: 1) Compared with the single-color element, the visual perception and cognition formed by multi-color superposition are more complicated; 2) The environment in railway is the space of commonality, it should cater with most of the people, and not for the single one. The color combination is too complicated to cater to most people's aesthetic preferences.; 3) The user's color preferences are very different, and it is impossible to accurately capture and cater to (G. Hu et al., 2015). For these reasons, this research aims to explore the harmonic and reasonable relationship of CTCC in the HSR`s environment as the preliminary sample. Based on the system architecture proposed in the previous work (L. Shi, 2021), this research proposes an HSR interior environment interaction system based on Chinese traditional color aesthetic principles and design principles. The purpose is to obtain the color-matching data on the CTCS characteristics suitable for humans.

6.2 Research Method

For the modern design industry, the relevant design process through digital methods can save development costs, speed up work efficiency, and obtain better visual effects, thereby obtaining accurate positioning of the content of the design (Shin & Westland, 2017). At the same time, it also needs attention from the past. The function and performance of the product to the current product experience and feelings of consumers (Nagamachi, 2003). According to the ergonomics point of view, human experience and feeling belong to the cognitive layer and perceptual layer, which mainly refers to the feeling and perception form that people produce on objects. The environmental context will affect people's perception of surrounding things, and feelings and emotions will affect users' perception and judgment (Y. Lin, 2019b). For color design, from idea to finished product or environment is a complete chain connected. This chain connects the color itself (that is, the human emotion and feeling) and production, including A. Creative feeling and concept; B. Visual analysis of the environment and texture of the material; C. Planning and selection, and establishing the final color concept; D. Explain the selected color; E. Carry out production and control the selected color.

Essentially, human perception or perceptual cognition is controlled by visual quality and determines the evaluation of perception. Physical conditions such as the light source and color tone are just the way to achieve visual quality. Visual comfort is the aesthetic experience of the environment, a continuous spatial experience that includes time and action, and includes space and linear continuity. The characteristics of visual content are shape, color, line, texture, proportion, and continuity. The evaluation and quality assurance of visual quality includes vividness, completeness, unity, sense of place, sense of belonging, etc. On the other hand, under the condition of the same lighting, the color harmony of the color scheme method is the main reason for the visual comfort. The environmental color configuration mainly includes color harmony, color preference, and the perceptual characteristics of color space. Color harmony relates to people's satisfaction with the quantity or two or more colors in parallel, which is one of the main contents in color comfort research.

For this study, the viewpoint thinks that the single-color element could not express cultural attributes and satisfy perceptual needs. Only through the sorting and recombination of color groups can the expression meaning with national characteristics be formed, and then people can get a sense of comfort. But this perceptual approach requires a process of digital quantification and analysis. The system of this study follows the above principles and realizes the extraction, generation, and optimization of traditional Chinese color matching cases of Five-Color combinations through the operation logic set by this research. In addition, the system uses built-in data and logic settings to assist users in creating a space color scheme for the training environment that they believe is beautiful and comfortable with Chinese traditional styles in a short period.

6.3 System

6.3.1 Operation Logic

The operation logic is mainly divided into four steps: 1. The color scheme and extraction of traditional Chinese artworks, and the system generate corresponding color plates according to the color trends of the user's selections and shift to cater to their preference, during the interaction procedure. 2. The system will record the color matching information and provide the generalized aesthetic score of the color palette. 3. the system will optimize and regenerate the color scheme based upon the user operation until the user is satisfied with the color scheme. 4. Collection of interactive coloring results. The backstage of the system will record every parameter in the user's operation process, such as user operation time, color matching optimization times, etc., as evaluation data.

6.3.2 Algorithm Model Architecture

The model architecture is based on our previous research work (L. Shi, 2021) in chapter 5. Three research models were used to construct the model architecture, which are the lasso regression model (S. Lin & Hanrahan, 2013b), the Neural Image Assessment (NIMA) model (Talebi & Milanfar, 2018), and the Wasserstein GAN gradient penalty (WGAN-GP) model (Gulrajani, n.d.), please check the detail in chapter 5.

6.3.3 Model Structure

The website system of this study is built by Three.JS, which is the open-source framework. The HSR model is based on the CHR2 second-class seat model. The training model is established in 3Dmax version 2020 based on the real train data.

The system provides customizable train internal components. The participant can through the interaction process with the mouse to adjust the main components of the three-dimensional space, please check the detail, as shown in Figure 6-2, and according to their preferences for color matching operations and customized environmental color settings. Five customizable color parameter group options, such as seat surface, wall, floor, ceiling, and window shading board, that those components are shown in Figure 6-1.

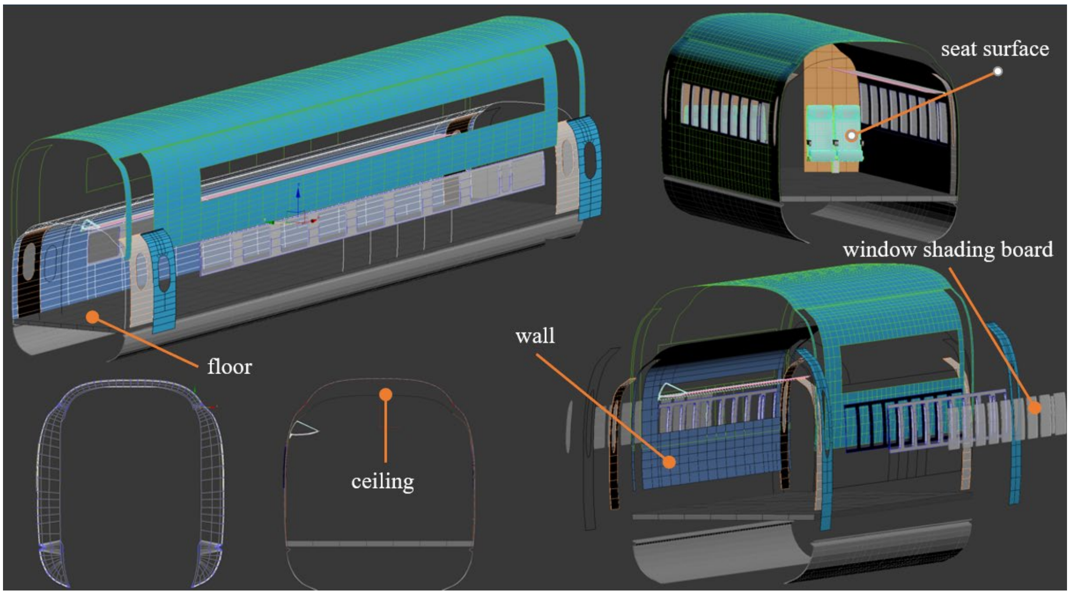


Fig. 6-1 Railway Model Structure

6.4 Experiment

6.4.1. Participants

We conducted a user study and we distributed our web and operating instructions to the public by WeChat Platform. During the experiment, the interactive program database collected a total of 95 valid user information, including 62 males and 33 females. There are 26 people with design or aesthetics majors and 69 people with non-design majors. Before the experiment, each participant was tested for color-blindness using the Ishihara Color Vision Test. Participants were confirmed to have no mental illnesses or psychological problems.

The Weblink： http://114.55.166.12:23225/autocolor/index.html

6.4.2 User Operate Progress

Each participant needs to be complete an experiment according to the operating instructions. The instructions that should be read before the experiment, it is shown in Appendix II. Otherwise, the system will not record any data and do not carry out the next-stage operation, thus ensuring the validity of the recorded data. Specifically, the user needs to fill in the basic information first. In the experiment, the preset image range includes 100 images, the image attributes are three channels (R, G, B), and the resolution is greater than 300 DPI. The participant is asked to select a favorite image from the image group provided by us and upload it to the system, shown in Figure 6-2 (A). The system will extract and generate the CTCS corresponding to the hue based on the image uploaded by the user, such as Figure 6-2 (B) which is the original color scheme. The user can choose to use the color scheme or the system automatically optimizes the color palette according to their preference, such as Figure 6-2 (C) which is the after optimized color scheme. Whereafter, users are asked to choose the color scheme from the color palette to the environment of the HSR and use the 5-color scheme to combine a train color scheme that they think meets their aesthetic and visual comfort, shown in Figure 6-2 (D). In the end, participants need to fill out a questionnaire after completing the experimental test.

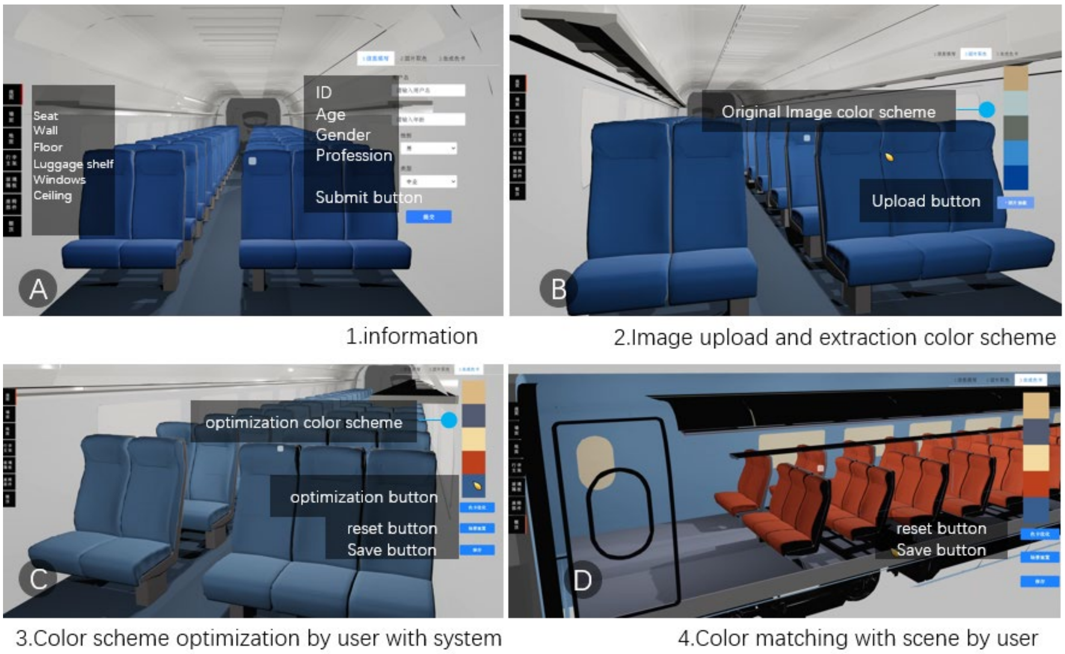


Fig. 6-2 User Operate Progress

6.5 Evaluation

6.5.1 Objective Evaluation

A. Aesthetic evaluation

In this part, the 40 experimental data had been used for the comparative evaluation. The comparative results are the original scheme and the optimization color scheme, which is shown in chart 6-1. The 3.00 is used as the threshold for evaluating the quality of the color scheme. From Chart 6-1, it can be seen the average value of the original results is 3.900, and the average value of the optimized results is 4.100. The aesthetic score of the optimized color scheme is higher than the result of the direct color scheme,

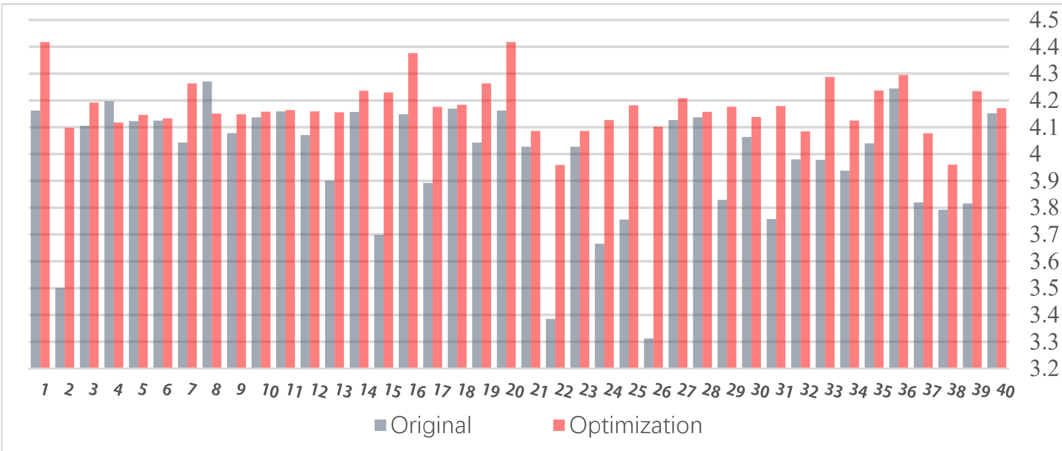


Chart. 6-1 The Score of Original Results and Optimization Results

B. Time evaluation

By comparing the data of 94 participants using the system with 10 participants operating who design the project by their way, the average operating time of professionals using this system is 260 seconds, the average operating time of non-professionals is 170 seconds. As a reference group, we have invited five design students and experts which are working with the general working flow， and without using a research system. The operating time by them is far more than 600 seconds. Therefore, through this system that it is possible to efficiently and

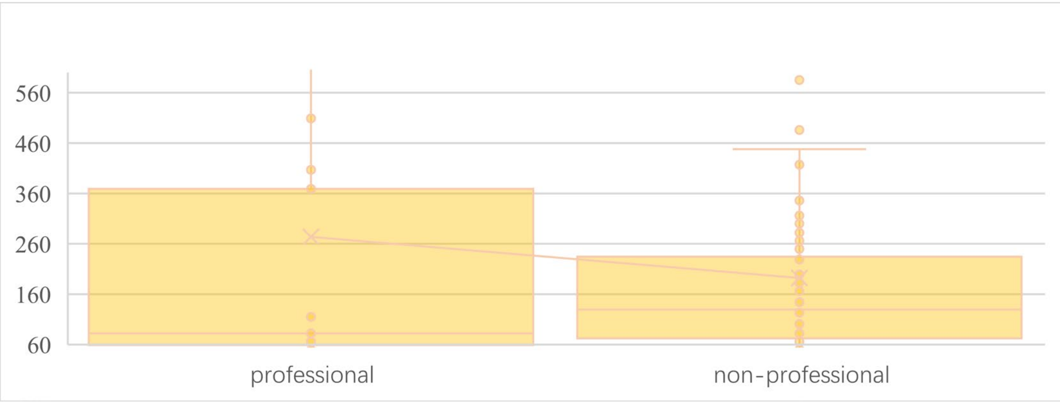


Chart. 6-2 Operation Time Comparison

save the time of the users. It narrows the limitation gap of requirements between professional and non-professional backgrounds. The operation time comparison is shown in Chart 6-2.

6.5.2 System Satisfaction Evaluation

The subjective evaluation includes the 5-level scale of five questions, 1 is very dissatisfied, and 5 is very satisfied.

Q1. Is the extracted color scheme accurate by your feeling?

Q2. Is the optimized color scheme to CTCS?

Q3. Compared with the un-optimized color scheme, whether the optimized color scheme meets your aesthetics?

Q4. Is this system helpful to you with color matching processing?

Q5. System Does it help you understand more CTCC?

The result is shown in Chart 6-3.

The system satisfaction survey, **Link: https://www.wenjuan.com/s/UZBZJv6J9DA/**

From the visualization result, it can be shown that regarding Q1, most experiment participants select 5, which proved this system can offer better color scheme results. Regarding Q2, this result has a large dispersion, indicating that the experimenter's understanding of CTCH is not high, resulting in uncertainty. Regarding Q3, it can be shown that the average score ranges from 3 to 4, which proves that many participants think that the result after optimization is better

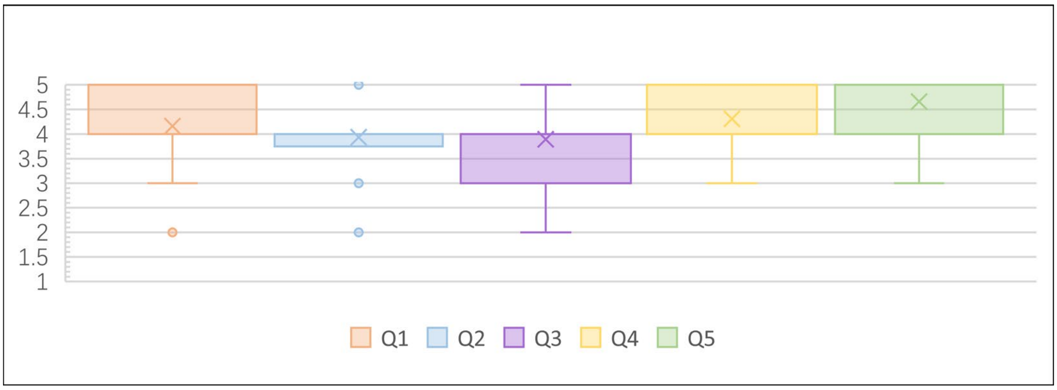


Chart. 6-3 System Subjective Evaluation

than that without optimization, so it is proved that the optimization of CTCS is satisfied with the aesthetic way of most participants. Regarding Q4, the result proves the system proposed in this work is approval by participants. Regarding Q5, although the result shows that the participants think that the system helps them, the view of this study is that this is a superficial phenomenon because the system only provides CTCS color matching process and images, but there is no related text description, that can`t help them understand deeply the CTCC knowledge, so it needs to be further improved.

6.6 Results

6.6.1 Original Scheme and Optimized Scheme

This part is the visualization reproduction of the data obtained from the experiment, that included two aspects: 1. the original color scheme data of the image uploaded by the user, the color scheme on the left is the reproduction of the color original results with the blue box, as shown in Figure 6-4. 2. the results of the color scheme data optimized by the user through the system, the palette, and the image on the right is the reproduction of the color scheme with the red box, as shown in Figure 6-4.

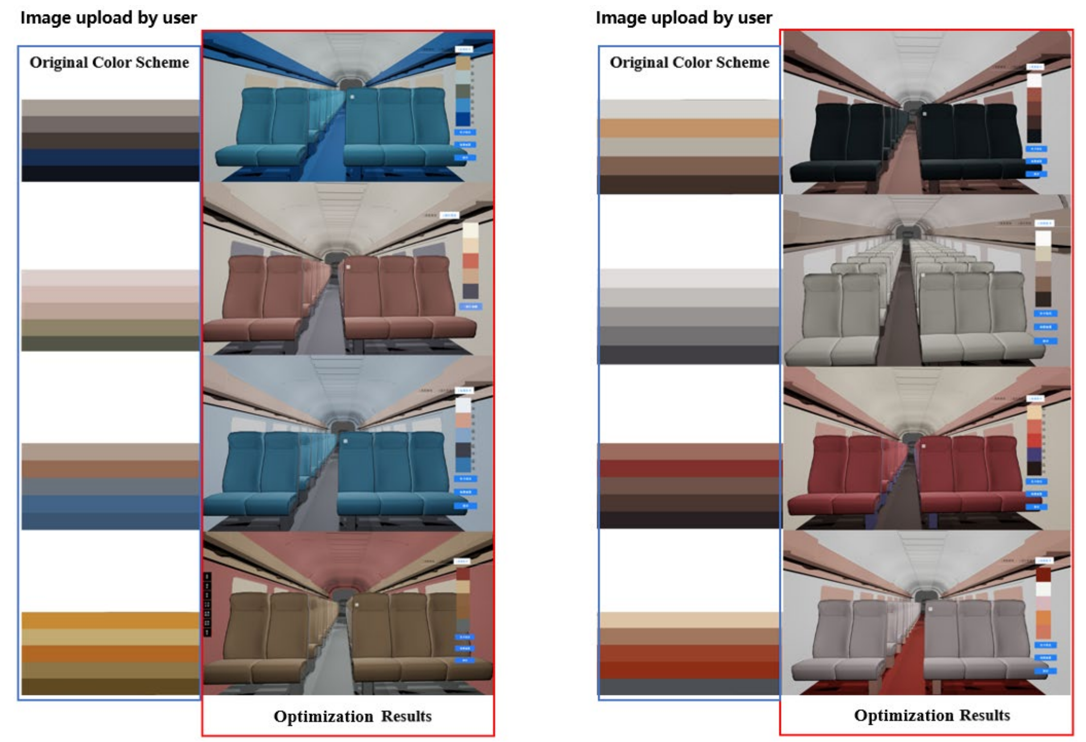


Fig. 6-4 Visualization Reproduction of the User Data

6.6.2 Dominant Tone and Minor Tone

The visual proportions of the dominant tone of the space color scheme and the minor tone are the main factors that form the image of the color scheme. Based on the results of the experimental data, we found that the number of clicks and modifications on the walls and seats by the experimenters averaged more than 3 times, shown in Chart 6-4, which proved that the seats and walls in the HSR environment space occupy the visual focus. This conclusion is consistent with the research results(J. Wang et al., 2021). At the same time, to further the perceptual cognition formed by the main tone and auxiliary tone of the picture, we used IRI`s (Image Research Institute Inc) perceptual cognition method of color to classify the dominant tone and minor tone(M. S. Lee et al., 2012). Due to the limitation of the scope and quantity of experimental samples and data, the preliminary results are analyzed as examples. Through the suggestions of 10 color experts, based on the partial classification results of 95 experimental samples are shown in Figure 6-5， the left side of the color scheme which is struct by two colors is the Dominant Tone, and the right side of the color scheme which is struct by two colors is the Minor Tone.

Chart. 6-4 Position Selection Frequency

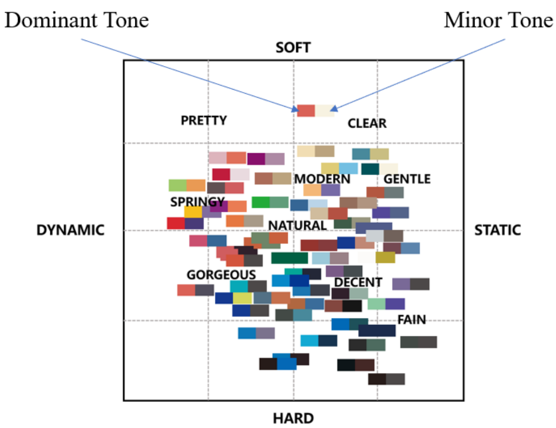


Fig. 6-5 Dominant Tone and Minor Tone

6.7 Discussion and Limitation

Through the experimental results and evaluation, it is shown that the interactive system can effectively generate, optimize, assist in creating and obtaining the CTCS for the user's HSR interior environment, and improve the color matching efficiency. However, there are two limitations.

1. Limitations of the data range. Traditional Chinese color culture is extensive and profound. Although several types of data, such as Dunhuang murals, Chinese traditional apparel, Chinese traditional textiles, and Chinese ethnic minorities have been integrated with the work, the data range needs to be gradually improved and supplemented with various approaches.

2. The limitations of hardware equipment. When building the website interactive system, the conditional differences in the hardware performance of each participant's equipment that had been considered, to ensure the accuracy of the color value and improve the fluency of experimental operations, the work reduced the interactive system visual effects and material effects. This work reduced the visual effect in an interactive environment, the fact had been considered, that the performance of users` computers limitation which may be operating with high visual quality, therefore website system had a low setting with visual effect. In the future, the work will consider improving the visual effect of the interactive environment on the premise of ensuring the fluency of the system.

6.8 Conclusion

The focus of this research is to explore a method of integration and blending, namely color quantification and interactive design, to expand the scope of application of CTCS systems. The two systems proposed by the research simplify the process of interactive operation. The unique colors of traditional Chinese culture are coordinated with design elements and design guidelines, and through the behavioral process of human-computer interaction, they can be transformed into each other and conform to human aesthetic preferences. Reduced the dependence of color scheme design on professional knowledge, improved the efficiency of color scheme design, obtained train color scheme data with CTCS characteristics, and carried out preliminary quantification of perceptual factors.

The research proposed a systematic method, which can provide more exploration ways through the conversion of models and contents. Because the CTCS method is not only satisfied with the human visual pleasure, it is a kind of aesthetic perception.

This unique insight is precise due to the continuation and inheritance of culture and civilization that it has gradually improved and formed the cornerstone of today's Eastern civilization. Color culture is an important means of communication. CTCC needs to continuously improve basic work and deepen modern people. The cognition and understanding of traditional color culture can continue to be inherited and developed.

In this research, the core work is focused and shown on interaction applications, but it is the caution that this article guides this interactive application through Chinese traditional aesthetic concepts and principles that are abstraction and complication. Through the process can provide the transformation of Chinese traditional aesthetics from theory to practice for interaction applications. In consequence, this work is utilized the interaction application way to show how to renew and use Chinese traditional color harmony with the specific area.

CHAPTER 7 A Virtual Reality Interaction Learning Application of Chinese Traditional Color Harmony

7.1 Introduction

7.2 Design ideal, Conception, and Principle

7.3 Research Method

7.4 Interaction Experiment

7.5 Evaluation

7.6 Discussion and limitation

7.7 Conclusion

Due to the limitation of visualization in chapter 6, to further streamline and optimize the user interaction process with knowledge transformation, this chapter proposed an interaction auxiliary learning application based on the two layers of semantic relations data, and the application system can assist the public to learn and understand CTCC and CTCH. First, through the participation experiment, two semantic relations had been established, that is the semantic relationship between sensation image and CTCS, Chinese traditional color, and Chinese Tang poetry. Based on the data of two semantic relations, the interactive virtual reality application is established which can help people to learn the cultural meaning of CTCC. By evaluating experimental results, it is proved people's interest in CTCH by the interactive VR application. It can help and assist people learn and understanding the CTCC and CTCH effectively.

7.1 Introduction

CTCC and CTCH are confronted with development problems. The literature has been illustrated in the first chapter. simultaneously, the more important reason is that contemporary Chinese people ignore the traditional culture for some reasons. Notably, CTCC and CTCH need a new approach to let contemporary people understand its meaning and aesthetic concepts and to develop and popularize this way of culture. The combination of color research and digital technology is undoubtedly the important development direction of CTCH for the future (Zeng, 2014). Additionally, CTCC and CTCH needed an understandable approach to make people know the brilliant cultural history of the past.

Similarly, the process of knowledge transfer and transformation is also a difficult and tedious issue. It is worth noting that, the best way to transform and improve the study and learning approach is to make the process more fun and interesting to users. Additionally, if this process could create a sense of physical and mental comfort, it will also increase acceptance of the process for people. With the emergence and popularization of virtual reality technology, this study believes that interactive processes and virtual reality technology can be used to increase the interaction in the process of knowledge transfer and transformation to make it interesting and funny.

As consequence, this chapter constructs two semantic relations as the data basis of the system and then establishes two layers of semantic relations, namely, the semantic relationship between adjectives and Chinese traditional colors. The semantic relationship between traditional color and ancient poetry. The interactive application system of this research is established through these two semantic relations. Finally, based on the semantic relations data from sensibility by people, an auxiliary interactive learning system of Chinese traditional color and culture is constructed, which adds interest and interaction to the process of learning and understanding. At the same time, it enables participants to acquire knowledge and increase their understanding of it.

7.2 Design Ideal, Concept, and Principle

7.2.1 Knowledge Transformation

Learning is defined as the process of gaining knowledge that belongs to the cause and the effect relationships (Shrivastava, 1983). In the process of knowledge transformation, it is necessary to elaborate the knowledge, identify the various representations of the corresponding concepts, and reshape the knowledge into a form that can be accepted and understood. (Shulman, 1987). The transformation of knowledge includes three stages: interpretation, representation, and adaptation (Wilson, Shulman, & Richert, 1987). From the perspective of cognitive science, knowledge must be organized into useful structures (Howard, 1987).

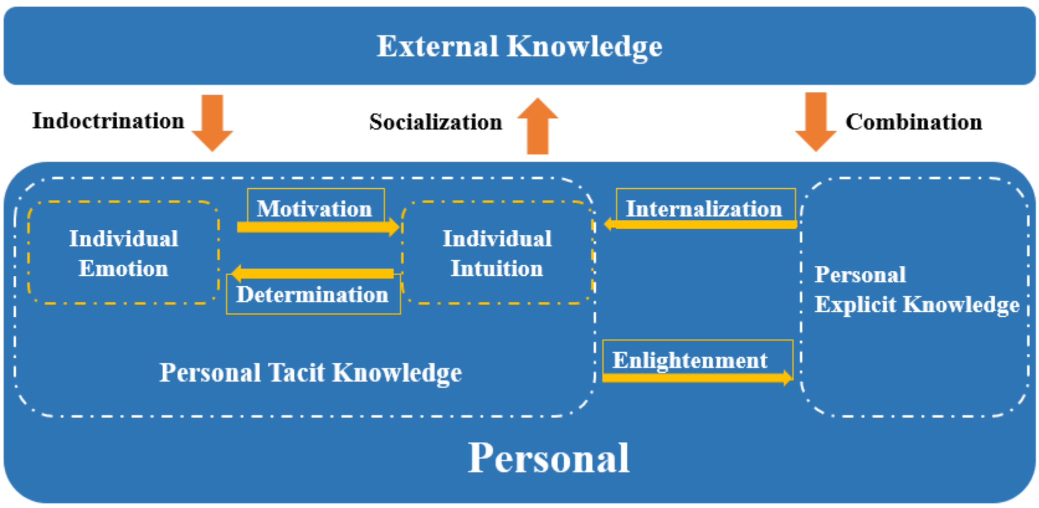


Fig.7-1 Knowledge Transformation

Knowledge is a process of transformation from a recessive state to a dominant state. Therefore, the tacit knowledge of CTCC and CTCH should be transformed into an organizational form that is convenient for the public to understand, as to promote the transformation into explicit knowledge. If the audience lacks conscious and active acceptance in this process, then the process of transformation is wrong and failed (Johansson et al., 2014). Among them, the visual information transmission is the suitable manner intuitive and effective. Therefore, this study hopes to realize the knowledge transformation process based on the concept of the knowledge transformation model as shown in Figure 7-1.

7.2.2 Aesthetic and Color Scheme

Whether any color combination meets the definition of harmony depends on the identity of social groups or individual preferences, and whether it is appropriate to define this group of colors (Westland et al., 2013). The consciousness of color aesthetics is not only closely related to the cultural problems of various nationalities but also corresponding to various stages of development and living standards. Color culture is the most prominent part of national cultural characteristics, and color can effectively express emotion (Hsiao et al., 2008).

The reasonable color combination can not only provide a pleasing visual experience but also meet people's psychological needs (Burchett, 1991). A comfortable feeling should be the result of balance (Gong et al., 2017b). For the balance of color scheme, the area ratio distribution of color can be determined according to the scale values of lightness and chromaticity, and the area is inversely proportional to each other, that is, the higher the lightness and chromaticity, the smaller the color area, and the lower the lightness and chromaticity, the larger the color area. The color with high brightness and color can be used as a bright embellishment color, forming the better visual result of color harmony. The context of color will affect the way people perceive color, and the result of people's perception of color will change due to the difference in the environment (Ou et al., 2011). The visual proportions of the dominant tone of the space color scheme and the minor tone are the main factors that form the image of the color scheme.

The influence of color on human senses has three levels. The first level is visual perception, which is mainly affected by the physical properties of perceptual objects and is closely related to color perception. The second level is psychological perception, and the result of perception is influenced by the individual factors of the experimenter. The third level is based on the interaction of the complex relationship caused by the interaction of the first two levels (Nemcsics, 2012). The visual proportions of the dominant tone of the space color scheme and the minor tone are the main factors that form the image of the color scheme.

7.2.3 Design Principle

The application program can be used as effective teaching and learning tool (Johansson et al., 2014). Due to the further expansion of the subject field of the integration of cognitive science into human-computer interaction, which includes cognitive psychology, artificial intelligence linguistics, cognitive anthropology, and philosophy of mind, human-computer interaction is one of the earliest examples of cognitive engineering (Carroll, 1997), (Treadaway, 2007). Additionally, with activity theory into HCI that has sublimated nature of HCI (Bazerman, 1998). The connotation of HCI is not only to explore the relationship between man and computer but also to describe how the change of consciousness is directly related to the current material and social conditions with people. With the maturity of virtual reality technology and hardware equipment (Diemer et al., 2015). The definable interactive environment provides a medium for human-computer interaction. Embracing emotions and affect is expected to enrich human-machine system research even more(Computer, 2005).

Based on the above point of view, this study believes that through the establishment of a standardized system process, interactive applications and VR patterns can increase the interaction and interest in the process, and facilitate the process of knowledge transformation. In the virtual reality environment, the human brain can creatively perceive objects that are a transformation procedure of knowledge, which can enhance intention to assist humans to learn (Shen et al., 2017). To promote the transformation of CTCC and CTCH from tacit knowledge to explicit knowledge. Finally, to achieve the purpose of assisting non-professionals in the learning process and increasing the cultural awareness of people with the professional.

7.3 Research Method

Overview

The system was built by using the UNITY platform. Based on the principle of dominant tone and the minor tone, this work had established corresponding tags with double semantic relation, the users only need to input the preferred perceptual color with the palette of CTCS with their preferences. At the same time, the system can display the original image of the color scheme and the Chinese traditional poetry (CTP) and the image to achieve the aim of knowledge transformation. The Procedures process is shown in Figure 7-2. First, the basic data of semantic relation, as input data to the system backstage that can offer the fundamental date for two stages in the experiment. Finally, the semantic relationship between CTC and adjectives offers the system backstage data connection with stage 1, for CTC colors with scene elements in stage 2. The semantic relationship between CTC and CTP offers the system backstage tags and the data for system output the CTP in stage 2.

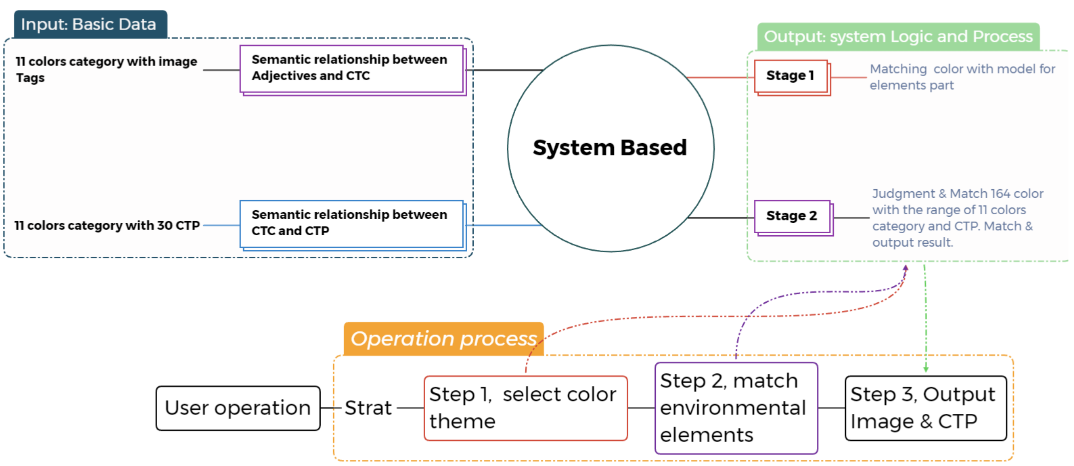


Fig. 7-2 Procedure Process

7.3.1 Semantic Relation

a. Semantic relationship between adjectives and CTC

In this section, to obtain the semantic relationship between adjectives and CTC, in the work, 10 students were invited to manually classify 50 CTAW according to their subjective feelings. In this part, a total 300 of different hue images of CTAW had been used as the selection range.11 folders of CTC were set up on the computer which is corresponding to the 11 dominant colors in CTC with a range of 164 colors, such as brown, red, orange, yellow, green, cyan, blue, purple, golden, white, and black. Each participant needs to put 50 images into the folder under the feeling. Finally, all the experimental results are integrated as the corresponding images of the corresponding 11 dominant color data. One sample case is shown in Figure 7-3.

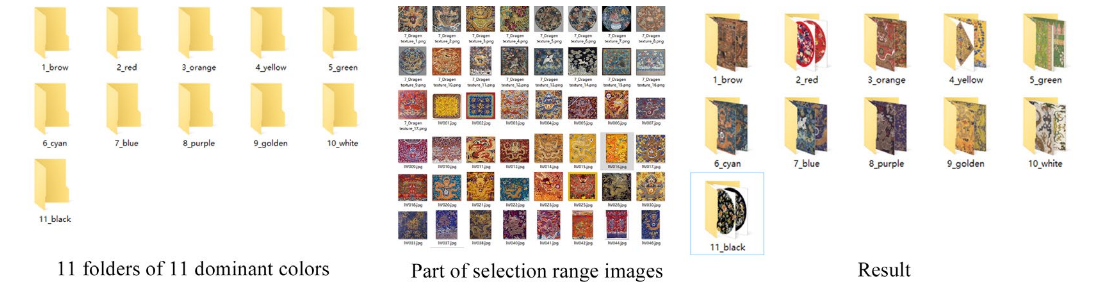


Fig. 7-3 Sample Case

b. Semantic relationship between CTC and CTP

Tang Poetry reflects Chinese traditional culture and is deeply loved by Chinese people. To obtain the semantic relationship between CTCH and CTP, a questionnaire had been made which included 20 CTP and the 11 major HUE within Chinese traditional color standard.

In this part of the experiment, the categories are represented by integers from 1 to 11 for the major 11 hues which are based on Chinese traditional color range, please refer to Appendix I, with the selection from 1 to 11 being brown, red, orange, yellow, green, Cyan, blue, purple, Golden, white, and black. Due to the Chinese traditional color standard that has been quantified in the previous work, the range and specific color can be divided by 10 kinds of hue in this part. In this section, a total of 20 CTP and their corresponding translations are displayed in each item. An experimental webpage sample with four CTP and the option with 11 dominant colors are shown in Figure 7-4.

The link to the experiment web page is as follows: **https://www.wenjuan.com/s/ueaQVjB/**

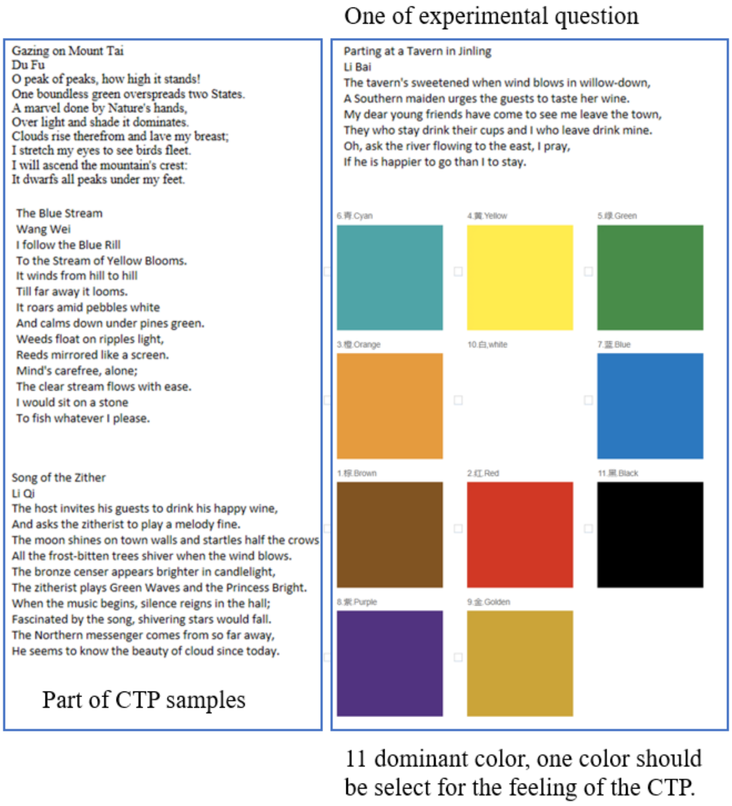


Fig. 7-4 CTC and CTP Experimental webpage

7.3.2 The System

a. System logic and equipment

This work is mainly based on the dataset established by two semantic relations. The participants enter the system and use the palette of Chinese traditional 164 colors to match with the 5 parts of the element in the environment, and the background data of the system is classified according to construction data built by two semantic relations, to realize the conversion of the backstage data and the reverse output in the system. The user only needs to select the preferred colors to the elements, the system will display the corresponding color matching, and then the user needs to make a customizable color matching of the space according to the 164-colors of the Chinese traditional color standard, and finally, the system will match the database according to the user's results. output the original image and Tang poetry. To realize the process of visual cognition and knowledge transformation.

b. VR equipment and controller

The computer which parameter is CPU I7-9700K, 3.6 GHz, Memory type DDR4 16G 3200MHz, GPU NVIDIA 2080. The VR equipment is HTC VIVE pro, the brain wave testing equipment is LOOXID, as shown in Figure 7-5.

Fig.7-5 The VIVE pro and LOOXID

Control equipment and functional logic. Participants can use the VIVE hand controller to achieve three functions, the hand controller is shown in Figure 7-6. 1. Selection function which is through the point to object target by ray, can be confirmed by the button of the VIVE left-hand controller. 2. Movement function in space. This part of the function is realized through the touchpad of the controller. 3. Hide and display the 164 color palette through two side buttons which are via once press to hide and double press to display.

Fig.7-6 The Controller

7.4 Interaction Experiment

7.4.1 The Model

In the construction of an interactive environment, two models with traditional texture, and the model with modern abstractionism are constructed by software 3DMAX. Each model is divided into five sub-models and groups. The motivation of those contents aims to offer participants feeling interesting by viewpoint changes through the spatial perspective in the process of interaction, models are shown in Figure7-7. Afterwhile, four scenarios are built based on the UNITY platform to construct the interactive processing.

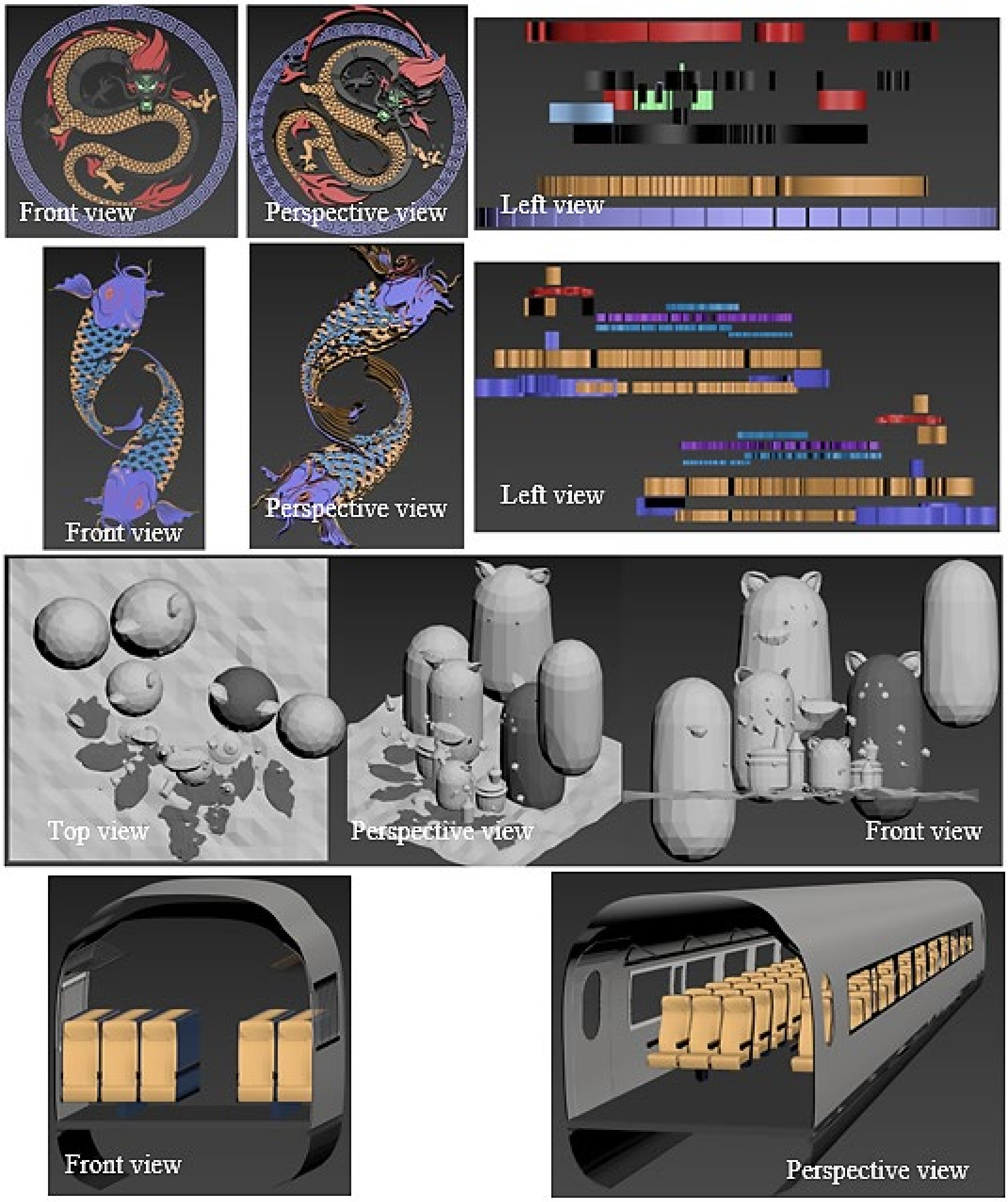


Fig.7-7 the models

7.4.2 Participations

In the prototype system experiment, a total of 12 people were invited to this study. There are 6 males and 4 females. The participants are all college students with an average age of 24. Before the experiment, the participants haven`t the problem with vertigo and color blindness in the three-dimensional scene.

Due to brainwaves are affected by sound factors (Y. P. Lin et al., 2010), to ensure that participants are not affected by external factors as much as possible, the experimental environment is chosen to set up testing equipment in a quiet space with sound insulation effect, and is chosen to start at 8 p.m. Experimental environment with a participation case is shown in Figure 7-8. Before the experiment, participants were briefed about the experiment process. The participants were requested to take the whole experiment in 1 minute for each scene. After the experiment, participants were asked to answer some questions about the experiment experience.

Fig. 7-8 Experimental Environment with A Participation Case

7.4.3 Interactive scenes and procedure

The interactive system consists of three scenes, as shown in Figure 7-9. The model components of scene 1 to scene 4 are from simple to gradually complex, and the models of scene 1 and scene 2 choose the pattern with Chinese traditional style as the model. Scene 3 chooses a modern model style and scene 4 is the interior space. Based on the system logic, each scene can be divided into two stages from the point of view of function, the first is the color matching stage, and the second is the observation output results stage.

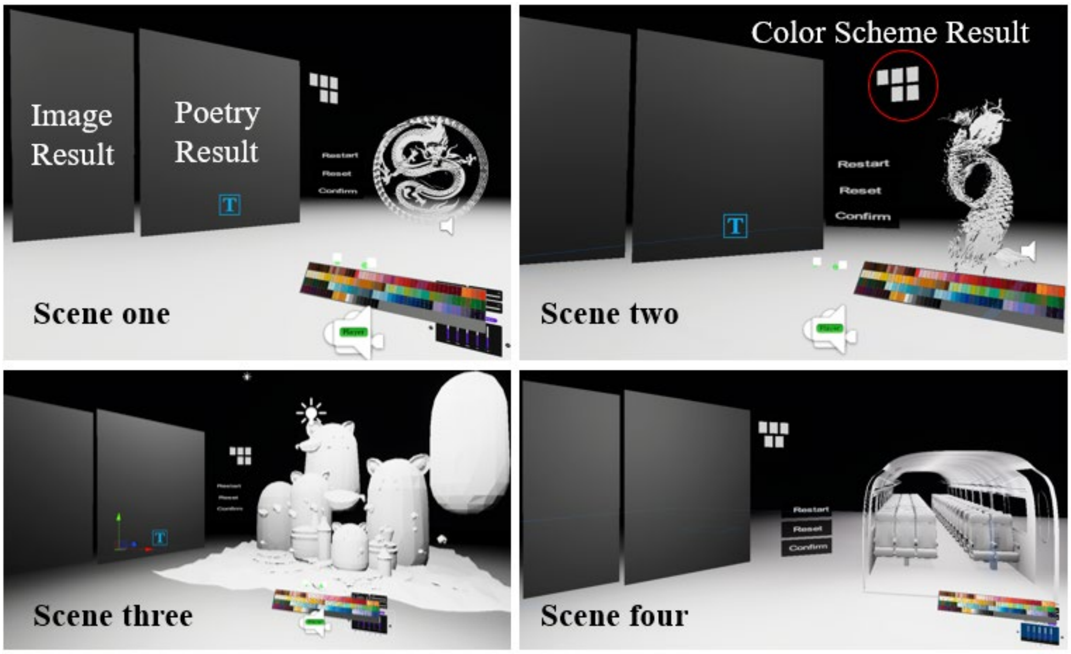


Fig. 7-9 the scenes

The first stage is the color matching period. It is mainly composed of four parts: First, the color palette area, and component button of the scene, the color palette is composed of 164 colors of Chinese traditional colors which are obtained from chapter 4, the color palette is shown in Figure 7-10 (A). The user can use those colors to change components in the scene until satisfaction with their preference. Whereafter, the participants can press the confirm button to the second stage, if the user thinks the color matching of the scene is finished. Second, the functional button that is shown in Figure 7-10 (B), contains three functions. Reset button which can reset the colors of all components in the scene. Restart button which can begin from the first scene. Confirm button which contains two pieces of logic to save the current user color. When the participants think the current color matching is satisfied, will enter the second stage. This part is the result output interface, the system will match the system data according to the color matching selected by the participants. Finally, the system will output two items which are the original images and CTP, which are according to the matching result of the color scheme by participation. Two pictures with and two CTPs will be shown, the case with the sample is shown in Figure 7-11 (A).

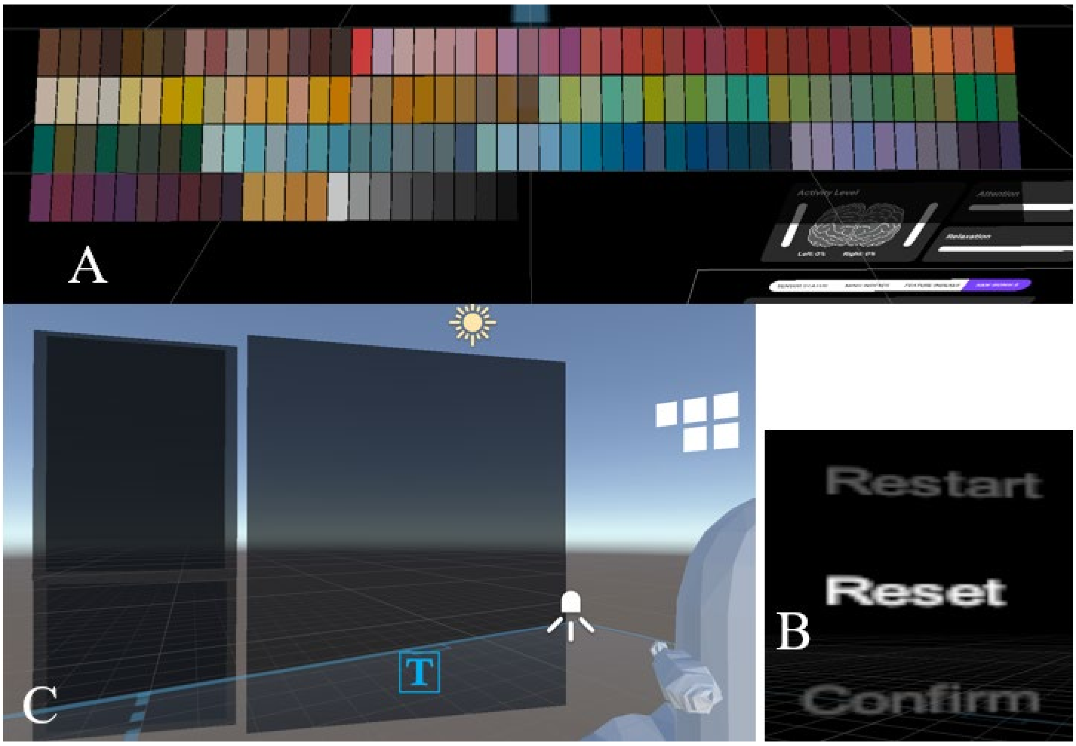


Fig.7-10 Function of Each Part in Scene

Additionally, the system can acquire the participation brain wave data which only can be displayed on the computer screen for the observer, the attention weight is the key data for evaluation. Therefore, based on the official API code within the UNITY platform provided by the LOOXID official website, the numerical changes of attention weight data of participants can be observed directly through visual data in the experiment, the part of the brain wave user interface is shown in Figure 7-11 (B).

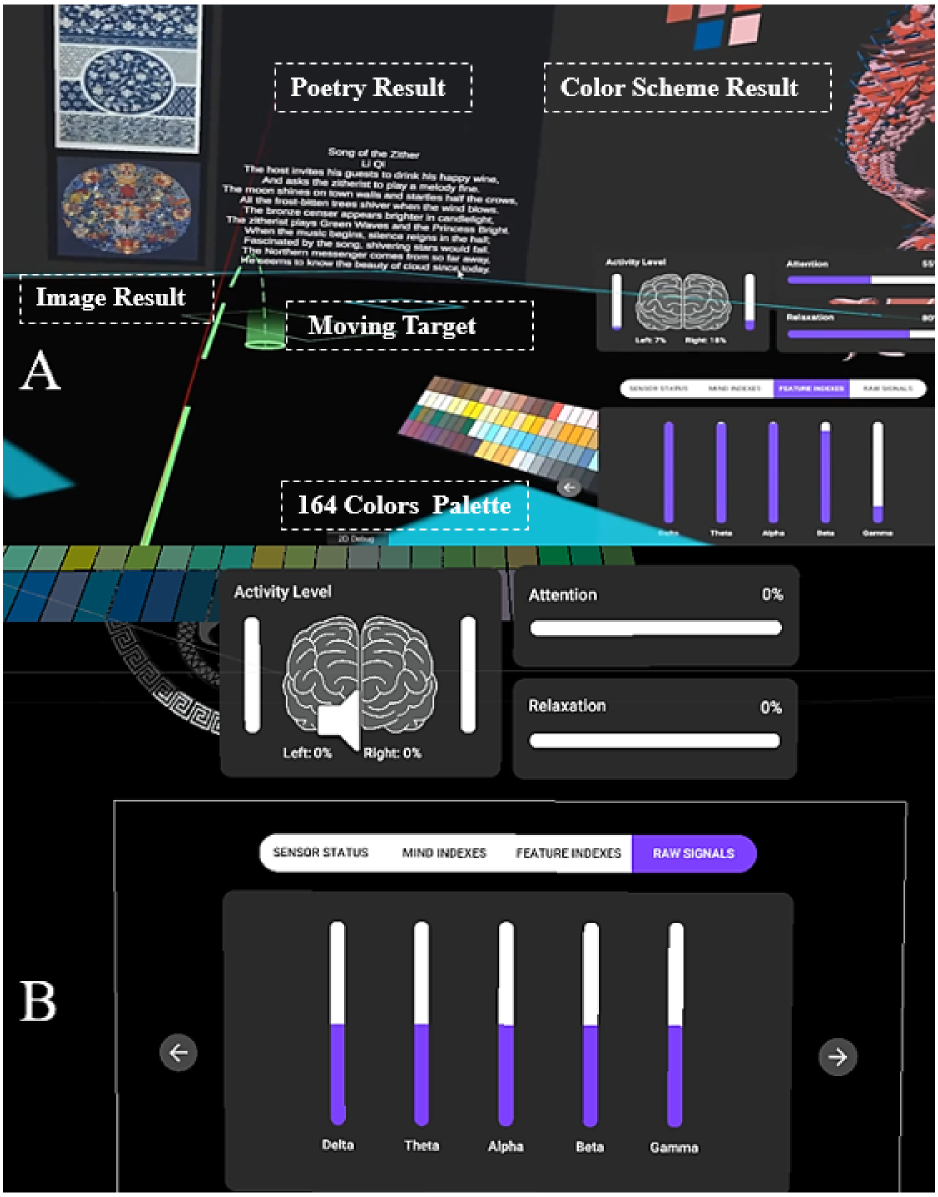


Fig. 7-11 Case with The Sample and Brain wave UI

7.5 Evaluation

7.5.1 EEG Evaluation

The electroencephalogram (EEG) is an important window for scientific insight into the internal functional activity of the brain (Xing et al., 2019). The measurement of EEG in the scalp of the subjects is a non-invasive method, which can be widely used in scientific research and clinical practice. EEG has become a popular and convenient technique, which plays a wide role in the research of aesthetics (Guo et al., 2019), music emotional feedback (Y. P. Lin et al., 2010), clinical and spiritual research, etc. (Joshi & Ghongade, 2020). According to the form of feedback, spirit feedback can be divided into visual feedback, auditory feedback, and tactile feedback. Among those, visual feedback is the most widely used, because vision plays a dominant role in the senses of receiving information.

To further verify the interactive procedure effectively, the LOOXID brainwave device is used in the work, which can be used as an effective brainwave extraction tool (Choi & Lee, 2020). It can acquire the visual brainwave data of the participants and measure the brain wave value and visual thinking index in real-time (Kameda et al., 2021). The data of brainwave record point of each participant were obtained by every 3 seconds as a timecode, the whole experiment processing of participation takes 1 minute for each scene. The samples with the brain wave of the participation interface are shown in Figure7-12.

Fig. 7-12 Samples with The Brain Wave User Interface

Due to the difference in each participant's interactive behavior during the experiment, the data of the experimental process is divided into two parts: 3 seconds to 36 seconds is divided into color matching interaction stage. 39 seconds to 60 seconds is the observation system output stage. The horizontal axis is the timeline, the vertical line is the user ID sequence. Attention weight data of three scenes are shown from Chart 7-1 to Chart 7-4 separately.

	3s	6s	9s	12s	15s	18s	21s	24s	27s	30s	33s	36s	39s	Mean_A1	42s	45s	48s	51s	54s	57s	60s	Mean_A2
P1_S1	96	87	31	30	36	10	53	100	56	47	21	27	30	48	24	10	94	99	90	84	70	67.286
P2_S1	7	68	29	32	32	35	39	17	100	100	96	23	26	46.462	40	45	93	40	71	95	84	66.857
P3_S1	6	19	36	45	77	73	71	69	97	95	97	26	28	56.846	34	46	76	60	80	69	90	65
P4_S1	25	38	47	51	46	38	36	35	27	14	20	55	93	40.385	28	100	100	38	62	32	92	64.571
P5_S1	49	2	15	23	81	29	32	50	40	32	41	34	67	38.077	50	30	32	56	46	83	91	55.429
P6_S1	1	71	73	28	33	76	62	35	35	34	50	6	15	39.923	79	65	43	47	77	22	55	55.429
P7_S1	5	12	34	60	45	82	24	33	37	79	50	26	35	40.154	47	40	100	23	56	24	30	45.714
P8_S1	5	42	85	95	75	91	55	46	25	33	24	42	9	48.231	99	73	72	4	63	50	100	65.857
P9_S1	27	28	84	83	83	40	79	45	100	73	58	62	32	61.077	91	16	43	50	60	53	50	51.857
P10_S1	23	81	91	69	61	100	99	22	39	43	100	100	100	71.385	28	69	14	25	29	36	43	34.857
P11_S1	23	35	43	79	78	89	83	55	3	12	100	32	31	51	32	40	77	33	81	100	37	57.143
P12_S1	66	100	83	62	54	22	100	3	65	100	95	33	35	62.923	69	45	73	72	63	53	46	60.143

Chart.7-1 Scene One Attention Rate Data

	3s	6s	9s	12s	15s	18s	21s	24s	27s	30s	33s	36s	39s	Mean_B1	42s	45s	48s	51s	54s	57s	60s	Mean_B2
P1_S2	5	40	32	23	29	41	65	100	53	97	62	71	27	49.615	39	46	47	65	69	92	80	62.571
P2_S2	23	85	67	58	56	68	100	89	81	40	60	75	27	63.769	98	38	45	52	39	65	100	62.429
P3_S2	23	32	52	100	51	35	29	60	46	100	45	31	31	48.846	35	48	46	59	43	100	89	60
P4_S2	26	38	47	79	14	8	78	77	75	85	32	52	45	50.462	96	76	60	45	63	90	92	74.571
P5_S2	27	51	71	66	26	53	40	58	100	67	100	95	26	60	43	67	49	100	49	57	55	60
P6_S2	64	100	82	77	90	62	36	72	93	71	77	100	24	72.923	60	50	39	42	51	100	100	63.143
P7_S2	41	45	98	24	21	29	39	56	100	29	36	94	92	54.154	35	53	53	98	90	60	70	65.571
P8_S2	16	51	68	79	100	39	64	71	100	23	31	75	90	62.077	42	29	85	38	63	40	52	49.857
P9_S2	61	13	29	32	65	70	52	89	100	100	25	30	3	51.462	46	43	91	78	72	65	50	63.571
P10_S2	85	96	72	59	30	20	54	53	99	92	34	89	24	62.077	28	35	41	61	48	40	58	44.429
P11_S2	24	21	26	27	35	97	100	30	34	40	100	41	30	46.538	44	83	59	66	75	68	100	70.714
P12_S2	10	29	42	62	70	100	58	60	20	77	100	44	32	54.154	64	43	55	70	48	73	66	59.857

Chart.7-2 Scene Two Attention Rate Data

	3s	6s	9s	12s	15s	18s	21s	24s	27s	30s	33s	36s	39s	Mean_C1	42s	45s	48s	51s	54s	57s	60s	Mean_C2
P1_S3	31	41	62	54	43	24	62	95	97	30	31	32	47	49.92	87	100	33	41	31	38	30	51.43
P2_S3	100	92	39	35	35	60	68	9	14	51	100	42	33	52.15	42	27	44	94	97	89	27	60
P3_S3	23	38	50	85	78	68	77	100	49	56	67	33	25	57.62	22	70	78	100	91	49	42	64.57
P4_S3	28	39	36	56	37	100	32	34	32	39	31	66	72	46.31	38	60	100	81	70	60	53	66
P5_S3	20	31	65	42	37	33	50	43	99	87	61	48	43	50.69	25	47	23	100	33	34	32	42
P6_S3	25	93	33	34	31	73	99	22	55	24	61	30	100	52.31	26	56	77	31	76	30	81	53.86
P7_S3	34	100	91	31	24	77	91	41	20	27	38	57	52	52.54	100	61	39	92	90	82	68	76
P8_S3	4	9	25	39	87	92	66	12	25	37	100	66	32	45.69	82	32	33	32	34	40	42	42.14
P9_S3	44	73	70	73	5	26	42	70	55	56	37	2	37	45.38	63	71	63	37	100	93	32	65.57
P10_S3	12	33	94	36	31	31	42	58	100	92	44	58	28	50.69	26	76	100	28	33	40	45	49.71
P11_S3	22	100	67	39	32	40	100	49	27	20	33	55	51	48.85	97	100	55	100	78	50	94	82
P12_S3	17	30	41	64	60	21	61	100	70	44	100	30	38	52	38	44	23	100	100	90	75	67.14

Chart.7-3 Scene Three Attention Rate Data

	3s	6s	9s	12s	15s	18s	21s	24s	27s	30s	33s	36s	39s	Mean_D1	42s	45s	48s	51s	54s	60s	Mean_D2
P1_S4	20	90	75	74	57	40	43	48	40	60	75	71	82	59.615	56	98	95	100	94	28	78.5
P2_S4	63	40	91	45	64	100	80	65	64	44	73	95	89	70.231	100	98	86	62	50	100	82.667
P3_S4	40	58	57	52	30	42	60	77	62	50	72	40	52	53.231	66	80	70	72	95	68	75.167
P4_S4	32	36	33	45	58	42	70	52	59	85	81	40	70	54.077	72	85	52	56	49	49	60.5
P5_S4	62	62	71	65	66	59	51	48	59	66	48	72	49	59.846	72	55	86	96	60	72	73.5
P6_S4	82	75	59	81	73	60	62	49	58	53	70	62	77	66.231	81	86	99	90	92	78	87.667
P7_S4	26	19	59	72	62	80	65	62	84	73	73	60	69	61.846	43	81	86	79	86	66	73.5
P8_S4	46	51	32	49	61	53	50	72	90	50	86	51	82	59.462	92	89	90	66	85	76	83
P9_S4	60	55	58	30	62	50	42	45	68	77	51	58	63	55.308	60	74	73	78	66	50	66.833
P10_S4	19	72	79	60	82	57	63	60	49	76	73	51	80	63.154	90	99	84	89	77	83	87
P11_S4	56	52	48	72	40	59	20	62	59	66	75	46	68	55.615	72	66	69	50	49	43	58.167
P12_S4	20	55	63	59	72	43	51	69	62	85	93	85	99	65.846	100	95	93	82	90	88	91.333

Chart.7-4 Scene Four Attention Rate Data

In the brainwave change curve, the longitudinal axis is the number of the participants' attention, and the concentration weight is from 0 to 100. 40 is the lower concentration baseline, and when the concentration is higher than 60, that means the attention rate is higher (Xiao Liu, 2020). In general, the concentration of the effective brainwave curve, that the smaller the fluctuation of the amplitude, the less the cognitive effort of the participants and the lower the level of attention caused by stimulation. When the fluctuation is large, the participants invest more cognitive attention and the level of doctrine caused by stimulation is higher.

Scenario one compares the result is shown in Chart 7-5. A1 represents the mean of the color matching phase, and A2 represents the mean of the observed output phase. The means and standard deviations of A1 and A2 are 50.346 ± 3.474, and 60.036 ± 12.573. Cohen's d value is 0.42, indicating that there is a difference in attention weight between the two stages, but the difference is small. comparisons between A1 and A2 are shown in Chart 7-5. From the chart, it also can be seen that group A1 and group A2 are both higher than 40.

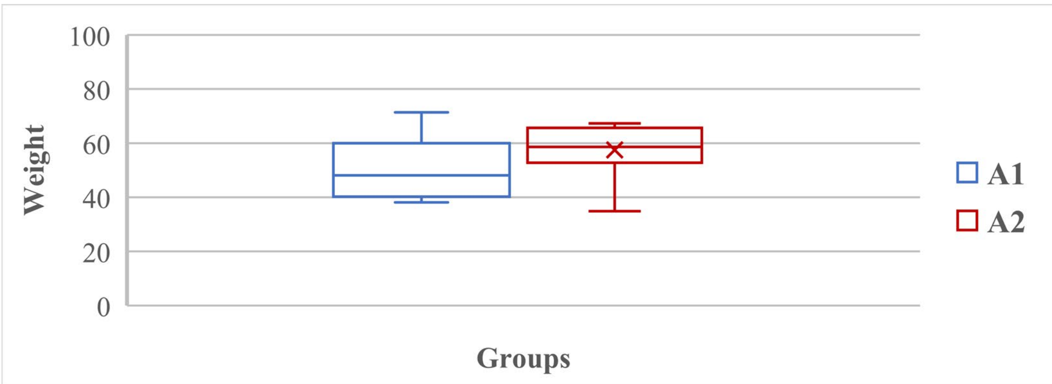


Chart. 7-5 Mean Score of Scene One

Scenario two compares the result. B1 represents the mean of the color matching phase, and B2 represents the mean of the observed output phase. The means and standard deviations of B1 and B2 are 56.34 ± 7.832, and 61.393 ± 8.064. Cohen's d value is 0.373, indicating that there is a difference in attention weight between the two stages, but the difference is small. The comparisons between B1 and B2 are shown in Chart 7-6. From the chart, it also can be seen that group B1 and group B2 are both higher than 40. Group B2 is concentrated at 60, indicating that experimenters pay more attention to the results.

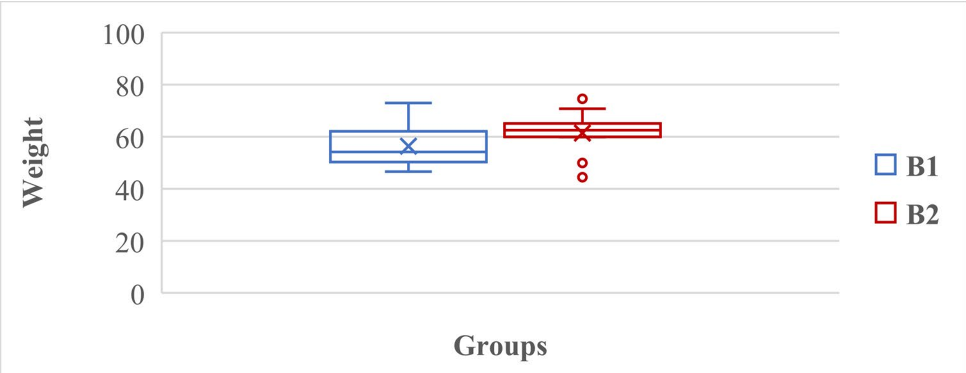


Chart. 7-6 Mean Score of Scene Two

Scenario three compares the results. C1 represents the mean of the color matching phase, and C2 represents the mean of the observed output phase. The means and standard deviations of C1 and C2 are 50.346 ± 3.474, and 60.036 ± 12.573. Cohen's d value is 0.768, indicating that there is a difference in attention weight between the two stages, The range of difference is moderate. The comparisons between C1 and C2 are shown in Chart 7-7.

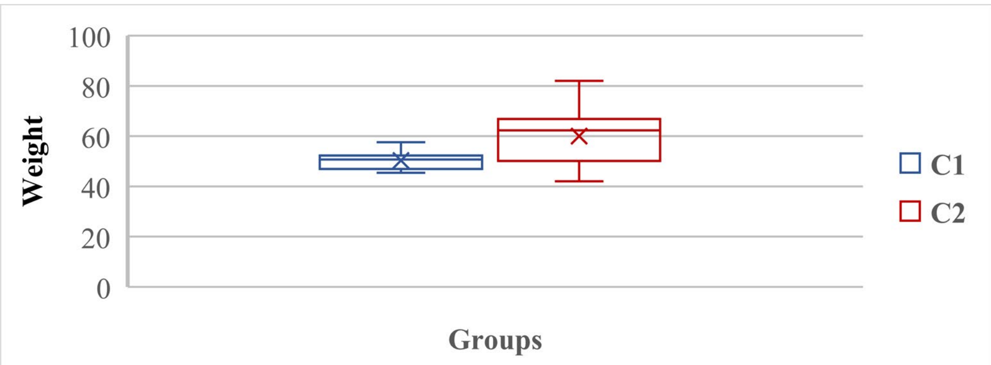


Chart. 7-7 Mean Score of Scene Three

Scenario four compares the results. D1 represents the mean of the color matching phase, and D2 represents the mean of the observed output phase. The means and standard deviations of D1 and D2 are 60.372 ± 5.326, and 76.486 ± 10.637. Cohen's d value is 2.162, indicating that there is a big difference in attention weight between the two stages, The range of difference is moderate. The mean score comparisons result between D1 and D2 are shown in Chart 7-8.

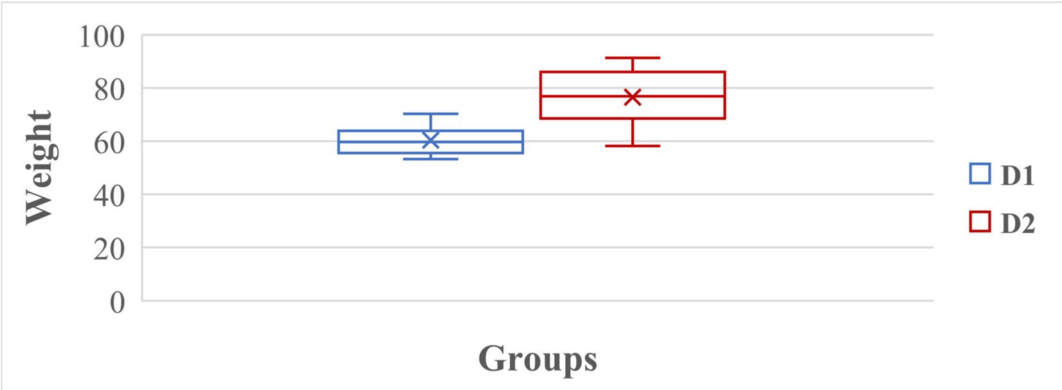


Chart. 7-8 Mean Score of Scene Four

Based on the results of the four scenarios, it illustrates that the system can attract a high attention rate of participants in the color matching stage, which proves that participants are interested in the system at this stage. In addition, the attention data in the observation stage is relatively higher than the color matching stage, which indicates that the observation stage could induce more attention rates for image and text content.

7.5.2 System Satisfaction Evaluation

The subject of evaluating the rationality of color collocation is human cognition, which will be affected by objective factors in this cognitive process (Nayatani & Sobagaki, 2002). Color recognition in images is a process of aesthetic cognitive behavior, which requires a certain process of cognition and transformation (M. S. Lee et al., 2012), (Nemcsics, 2012). In 1957, Psychologist C.E. Osgood created the semantic distinction method which is a method of experimental psychology. This evaluation method is widely used in the research and evaluation of perceptual and cognitive-related disciplines. The evaluation section had referred to approach from Chen's work question (C. W. J. Chen, 2015). The subjective evaluation includes an evaluation questionnaire with ten questions by 5-point Likert scale (1 = strongly disagree, 2 =

disagree, 3 = neutral, 4 = agree, 5 = strongly agree). Participants were asked to answer questions objectively and impartially to improve the shortcomings of this study. Before the beginning of this session, each participant was asked to browse traditional Chinese works of art and ancient poetry through observation and reading. The results are shown in Figure 7-13.

The experimental questions are following:

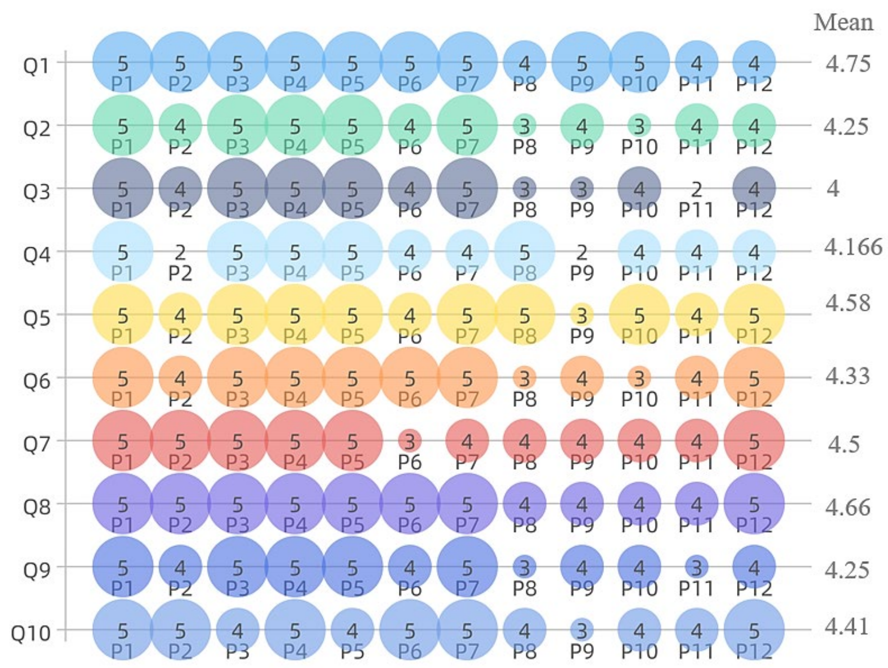


Fig. 7-13 Interaction System Satisfaction Survey

Q1. I think this interaction system is interesting.

Q2. I think the learning system can motivate me to learn aesthetic skills.

Q3. I think this interactive process is convenient to assist learning in color matching.

Q4. I think the learning system can enhance my knowledge and skills for Chinese traditional color culture.

Q5. I think the knowledge of CTCC and CTCH can be learned from the interaction the processing.

Q6. I think the learning system is better than the traditional learning way for culture.

Q7. I think the operation logic setting in the system can enhance my learning.

Q8. If this kind of system is used in class, will you like it?

Q9. What score would you rate the interactive learning system?

In this part, the questionnaire data are tested by Kendall's W method (Schuca, 1973), and the results of the Kendall coefficient consistency test show that the significance value of the overall data is 0.001**, which is significant on the level, that the data are consistent. At the same time, the Kendall coordination coefficient value of the model is 0.25. Therefore, the degree of correlation is general consistency, which proves that the system is satisfied with users.

7.6 Discussion and Limitation

Through the brainwave evaluation results, it is proved that this interactive system can improve the attention of the participants for the aim of learning, in the mass. In addition, the brainwave results were significantly improved in the display stage of specific content. It is further proved by the results of the questionnaire survey. For most participants, the original design intention of the system can be achieved, but individual users are not satisfied with some problems, such as participants of the eighth and the ninth, which may be due to dissatisfaction with the images and text generated by color matching, or this interaction mode does not reach their ideal state and other problems. To further seek the lack in the system, after the questionnaire survey, the participants were taken an interview and asked questions, and three main reasons for the lower 3 score that had been obtained.

The low-score reasons are as follows:

First, the content of text shown in the system is in English, which is not easy to understand for Chinese ancient poetry. If the original Chinese and English versions of the poetry can be displayed simultaneously in the results, it will be convenient for most people to understand and learn. Second, it will be helpful for participants to learn if the results can show the corresponding historical background of Chinese traditional artwork pictures. Third, the provision of traditional Chinese-style buildings or objects for color matching will help to improve the participants` learning process.

On the other hand, this study has two aspects of limitations:

1. Data volume of experimental samples. Two semantic hierarchical relationships were established in the work respectively, but the data volume needs to be further increased.

2. The function of automatic CTCH generation is not provided, which may cause inconvenience to users. In future work, it will be added the automatic generation function as used in chapter 6.

7.7 Conclusion

In this work, the main purpose is to cluster and quantify the semantic relations of CTCS features. This part built up the feelings and semantic meanings of various colors scheme are classified according to the sensuous words for the previous basic database. The system in this chapter is mainly through the interactive progressing to help people learn and understand how to use CTCS and the background knowledge of CTCC. This chapter constructs two semantic relations as the data basis of the system and then establishes two layers of semantic relations, The interactive application system of this research is established through these two semantic relations.

Finally, based on the two layers of semantic relations data from sensibility by people, an auxiliary interactive learning system of Chinese traditional color and culture had been constructed, which adds interest and interaction to the process of learning and understanding. Through the part of the evaluation, it has proved the system effectively for knowledge learning of the CTCC and the CTCH, but it also needs to improve further. Additionally, it enables participants to acquire knowledge and increase their understanding of it.

CHAPTER 8 Conclusion, Implication, Limitation, and Future Work

8.1 Conclusion and Implication

The power of intangible cultural heritage is noble, it is closely connected with natural culture, it is deeply combined with national root culture, and it protects the seeds of human culture. The birth of the list of intangible cultural heritage around the world shows that mankind has promoted the significance and value of national culture to the human level (Xiang, 2018). It indicates that mankind has realized that intangible cultural heritage as a living cultural heritage is the knowledge source of human cultural innovation and the importance of cultural identity and sense of history.

As an intangible cultural heritage, CTCC still shines brightly after wind and rain. CTCC has a history of thousands of years which can be date back as early as 1600 before the Common Era (BC),(T.-R. Lee, 2012). CTCH is an important part of CTCC and the important theoretical basis of CTCH. And the Five-Elements-Theory is one of the significant concepts in CTCH theory. It is a cultural model of Chinese civilization in the aesthetic concept (X. Zhang et al., 2012). Nowadays, CTCC and CTCH still have a far-reaching impact on contemporary CTCC and Asian color culture (Ishai et al., 2007). It has great influence and value in the field of art throughout China and the world. Traditional color culture is an indispensable part and important social element in the development and change of every social stage. The changes in various social stages have inherited and developed the traditional color culture of the previous society. Accordingly, to better integrate CTCC and CTCH. It should be studied with scientization manner, theory, and principle.

Answer for the MRQ and Theoretical Implications

MRQ: How to inherit and apply CTCC and CTCH with digital manners?

This dissertation through interdisciplinary approaches achieved the aim which had been proposed this dissertation had proposed a systematic methodology namely CID. Through the CID method, four aspects of CTCH inheritance issues had been solved partially. Compared with the existing research, the method proposed in this dissertation is the breakthrough with the Chinese traditional aesthetic theory and practical application in a new approach with digital manners. And the main reason is that the research has not limited to a single field and discipline restrictions.

The theoretical implication, firstly it had illustrated and explained how this dissertation is constructed from conception to establishment step by step detailly and provided an overall thinking process for the research. Secondly, it introduced how the methods had been structured from top to bottom through the mixing approach and literature analysis software. Thirdly it had demonstrated the data collection approaches with the each of links in the dissertation. As consequently, this methodology offered the case for related research which could be a reproduction of the work.

Answer for the SRQ with Practical Implications

The works had been the realization of interdisciplinary research, the specific conclusion and implication are as follows:

SRQ 1: How to establish the Digital Features of CTCH?

The number of Chinese traditional artworks is huge, and the artistic styles of different periods are different, it is very difficult to summarize and classify. The research motivation of this chapter is to transform the aesthetic experience of color experts and artists as a method to extract Chinese traditional artworks in batches.

In chapter 4, Extraction Approach of Chinese Traditional Scheme Colors based on Chinese Traditional Artwork. In this part, three tasks had been completed for the aim: 1. Collect and sort out verifiable images of CTAW for classification, and sample data extraction with the Chinese national color standard. 2. The fundamental dataset has been built for training Mask R-CNN. 3. The color extraction website tool that focuses on CTCS had been established.

The practical implication, this method can offer the classify and quantify approach for digitization CTCS.

SRQ 2: How to make CTCC and CTCH cater to the aesthetic of contemporary humans?

There have differences in aesthetic concepts, ideas, and aesthetic attitudes between the East and the West. Regarding the CTCH, how to optimize in an objective way to cater to the development of the time. It is essential to satisfy the demands of the aesthetic by modern people.

In chapter 5, the contemporary Chinese traditional color harmony inheritance method had been proposed. This method can generate CTCS and optimize CTCH. Based on the visual perception experiment, the work had been obtained the visual perception score of CTAW. Usage the participant's sensation scores data as an input baseline, and COLOUR LOVERS website data as the general aesthetic scores, to general visual perception rule which could suitable for the aesthetics of modern people.

The practical implication, this part offers the method of transformation from abstract to concrete for aesthetic knowledge. Additionally, the method offers the approach of renewing and updating CTCH, it can be referred to for other works of aesthetic.

SRQ 3: How to utilize CTCC and CTCH with reality and a practical approach that can make people use it and comprehend it?

Two systems had been proposed for this part which is to simplify the process of interactive operation.

In Chapter 6, An Interaction Website application of Chinese Traditional Color Harmony: the case of high-speed railway. It presents the usage of CTCH with the specific project. This part explores the localized design concept of HSR, expands the application scope of CTCS, and provides an effective method for inheriting Chinese traditional color culture. Its significance is to facilitate the collection and processing of perceptual quantitative data of CTCH, put forward the research method and process of the application of spatial color matching, and provide the research method and process of combining theory and practice for CTCH.

In Chapter 7, A Virtual Reality Interaction Auxiliary Learning Application of Chinese Traditional Color Harmony. The system in this chapter is mainly through the interactive progressing to help people learn and understand how to use CTCS and the knowledge of CTCC. This method adds interest and interaction to the process of learning and understanding for people. It enables participants to acquire knowledge and increase their understanding of it.

The practical implication, the method is proposed for learning knowledge of CTCH, the method can connect the knowledge with the CTCH and the CTCC.

Simultaneously, this approach is the combination of the aesthetic with the technology.

8.2 Limitation

In general, this dissertation has the following limitations:

(1) The data-level, CTCC, and CTCH are too complex and tedious, if want to sort it well that needs to be subdivided into various categories step by step, it still has a long way need to go. Simultaneously, the first limitation of the dissertation is the data that had been used for the training model. If to achieve high accuracy, that demand the massive data sets, the idealism required tens of millions and even more data accumulated, that is also a common problem in related research at present.

(2) Aesthetic evolution, As the person who defines aesthetics, with the development of the times and social changes, the definition of aesthetics has been given various definitions with different stages. This dissertation had presented the methods of improvement and development, but it also needs to be updated according to the social needs of the periods.

(3) The participant, in this work all the participants have come from China. This leads to limitations at the data level.

8.3 Future Work

As an intangible cultural heritage, CTCC still shines brightly after wind and rain. CTCC has a history of thousands of years. This work only involves the tip of the iceberg, there is still a lot of work that needs to be done, which requires various disciplines and fields to work together for it. I hope that with this work as a point, it will be gradually connected into a line for the future.

More importantly, the content of this work will continue, and the future work will be based on two aspects to further study the Chinese traditional color harmony. First, is the data level, that more kinds of Chinese traditional color harmony data will be further improved in the next work, such as the folk-art works will be sorted out and collected. Second, in terms of application, the work will consider expanding the research of Chinese ink art and further enrich the application research of colorless for color harmony through the aesthetic concept of ink depth change.

In the end, this dissertation is humble work, it is a simple work, it is a, but it is a meaningful view and method for the cultural inheritance. It not only regards CTCC and CTCH but is also suitable for any intangible culture.

Appendix I 164 Chinese Traditional Colors

The CTC Results of the Color Coordinate, the LAB and the RGB

Number Sequence	Hue	Color Coordinate			L,A,B			R,G,B			RGB color visualization
		Y10	x10	y10	L	A	B	R	G	B	
1.000		11.3	0.427	0.371	40.08	16.14	19.57	128	84	63	
2.000		9.3	0.420	0.381	36.56	11.67	19.33	113	78	55	
3.000		8.1	0.416	0.365	34.19	13.69	15.24	108	72	56	
4.000		4.9	0.376	0.341	26.45	9.445	6.006	80	57	53	
5.000		28.6	0.347	0.356	60.43	3.055	10.6	159	143	126	
6.000		11.6	0.414	0.408	40.57	5.582	25.28	117	91	54	
7.000		8.0	0.381	0.369	33.98	6.214	12.25	96	76	60	
8.000	Brown	34.7	0.375	0.346	65.51	16.02	12.77	195	148	136	
9.000		19.6	0.420	0.333	51.38	28.99	13.45	175	102	100	
10.000		38.6	0.345	0.344	68.46	6.884	8.082	185	162	151	
11.000		24.3	0.387	0.351	56.39	16.1	14.22	170	125	110	
12.000		23.3	0.420	0.360	55.38	22.03	21.06	179	118	96	
13.000		13.1	0.370	0.347	42.91	10.14	8.877	123	95	86	
14.000		7.0	0.424	0.345	31.81	18.62	11.99	107	63	56	
15.000		5.9	0.363	0.346	29.16	6.682	6.072	82	65	59	
16.000		61.7	0.319	0.315	82.75	9.456	-4.578	220	201	213	
17.000		57.9	0.324	0.303	80.68	17.05	-7.811	226	190	214	
18.000		63.9	0.347	0.331	83.91	14.67	5.538	241	200	198	
19.000		58.2	0.359	0.334	80.85	17.83	8.395	239	189	184	
20.000		52.7	0.363	0.326	77.7	22.24	6.208	236	177	180	
21.000		52.8	0.349	0.317	77.76	20.64	0.979	230	179	190	
22.000		41.5	0.409	0.335	70.52	32.8	15.96	237	149	144	
23.000		43.4	0.333	0.284	71.83	27.78	-11.99	216	159	197	
24.000		28.2	0.373	0.307	60.07	28.26	1.261	193	126	142	
25.000		26.9	0.394	0.290	58.88	41.12	-0.665	207	112	143	
26.000		18.5	0.355	0.246	50.1	42.82	-16.83	175	89	148	
27.000		26.3	0.469	0.339	58.32	43	24.58	218	107	99	
28.000		22.4	0.471	0.321	54.45	47.58	18.8	211	92	99	
29.000	Red	20.4	0.521	0.337	52.29	52.1	31.52	213	80	73	
30.000		19.6	0.543	0.361	51.38	48.3	43.2	208	82	50	
31.000		15.9	0.487	0.335	46.84	41.48	22.63	181	79	75	
32.000		14.7	0.506	0.311	45.22	52.05	19.16	189	62	77	
33.000		14.5	0.446	0.303	44.94	41.48	8.682	171	75	93	
34.000		14.0	0.509	0.320	44.23	48.87	21.53	182	63	71	
35.000		14.0	0.564	0.335	44.23	54.77	35.83	192	53	48	
36.000		12.4	0.527	0.354	41.84	40.47	32	167	67	48	
37.000		10.1	0.510	0.334	38.02	40.09	22.55	154	58	55	
38.000		10.0	0.531	0.337	37.84	42.82	26.49	157	54	48	
39.000		9.7	0.515	0.311	37.3	46.93	17.93	159	47	61	
40.000		8.7	0.510	0.328	35.4	39.72	20.2	145	52	53	
41.000		8.5	0.506	0.319	35	41.14	17.62	145	49	56	
42.000		8.6	0.463	0.286	35.2	43.09	5.721	145	48	75	
43.000		43.7	0.492	0.397	72.03	35.43	54.83	255	149	75	
44.000		39.5	0.504	0.386	69.11	41.3	52.42	255	136	73	
45.000	Orange	30.7	0.481	0.361	62.25	40.51	34.86	229	119	90	
46.000		27.5	0.460	0.371	59.43	30.42	32.31	206	121	87	
47.000		26.1	0.558	0.371	58.13	53.13	55.87	237	94	40	
48.000		79.8	0.341	0.348	91.6	5.126	10.97	250	227	209	
49.000		78.9	0.363	0.385	91.19	-0.853	28.07	248	229	175	
50.000		77.0	0.338	0.349	90.32	3.261	10.64	242	225	206	
51.000		76.9	0.327	0.345	90.28	-0.044	7.243	233	227	212	
52.000		74.5	0.395	0.427	89.16	-3.702	49.01	247	224	128	
53.000		71.9	0.391	0.398	87.92	5.34	37.53	254	215	148	
54.000		57.4	0.469	0.481	80.4	3.901	89.88	244	194	0	
55.000		57.1	0.446	0.492	80.24	-6.157	84.67	226	199	0	
56.000		54.0	0.362	0.392	78.46	-3.557	26.66	206	195	143	
57.000		57.8	0.402	0.388	80.63	12.5	33.98	243	190	136	
58.000		56.9	0.457	0.425	80.12	17.76	60.12	255	184	82	
59.000	Yellow	55.3	0.466	0.452	79.21	11.63	73.39	249	186	44	
60.000		53.6	0.399	0.364	78.23	20.13	24.92	244	179	147	
61.000		53.0	0.471	0.456	77.87	11.72	76.01	245	182	29	
62.000		43.2	0.509	0.434	71.69	27.77	76.12	249	154	0	
63.000		41.7	0.377	0.353	70.66	15.12	15.94	210	163	144	
64.000		35.9	0.390	0.391	66.44	6.061	27.69	189	156	111	
65.000		33.8	0.493	0.422	64.8	25.1	59.55	221	138	44	
66.000		32.5	0.489	0.444	63.75	17.61	66	209	141	17	
67.000		33.6	0.468	0.437	64.64	14.41	57.38	205	145	47	
68.000		28.7	0.430	0.416	60.52	9.636	39.4	182	138	75	
69.000		23.9	0.359	0.361	55.99	4.977	12.73	151	131	111	
70.000		22.9	0.447	0.418	54.97	12.52	40.36	171	122	60	
71.000		12.5	0.434	0.403	42	10.85	27.76	129	92	53	

Appendix I

The CTC Results of the Color Coordinate, the LAB and the RGB

Number Sequence	Hue	Color Coordinate			L,A,B			R,G,B			RGB color visualization
		Y10	x10	y10	L	A	B	R	G	B	
72.000		58.8	0.303	0.363	81.18	-17.41	8.369	173	211	184	
73.000		58.4	0.367	0.458	80.96	-22.79	48.68	189	211	106	
74.000		58.2	0.327	0.381	80.85	-13.62	17.72	188	207	166	
75.000		50.5	0.265	0.374	76.38	-36.84	5.521	105	207	176	
76.000		49.7	0.295	0.387	75.88	-27.78	13.48	139	201	160	
77.000		46.0	0.411	0.506	73.55	-19.39	71.84	182	188	19	
78.000		42.0	0.338	0.427	70.87	-21.86	29.88	153	183	117	
79.000		37.3	0.350	0.497	67.5	-33.96	49.01	129	179	69	
80.000		41.9	0.280	0.377	70.8	-29.24	8.008	116	188	157	
81.000		35.0	0.250	0.384	65.75	-41.5	5.457	52	179	147	
82.000		34.8	0.239	0.359	65.59	-39.1	-2.015	40	178	160	
83.000		35.0	0.409	0.465	65.75	-8.703	51.86	172	162	61	
84.000		34.7	0.347	0.454	65.51	-24.35	36.26	137	170	91	
85.000		32.1	0.332	0.396	63.43	-13.75	18.92	142	160	118	
86.000		29.4	0.304	0.340	61.13	-6.434	1.08	136	151	144	
87.000	Green	28.7	0.285	0.362	60.52	-19.81	4.139	109	156	137	
88.000		24.4	0.290	0.409	56.49	-28.84	14.76	87	148	108	
89.000		23.7	0.310	0.462	55.79	-33.68	28.23	86	148	82	
90.000		23.4	0.328	0.440	55.48	-23.73	25.99	106	143	86	
91.000		23.0	0.378	0.417	55.07	-4.551	28.07	141	133	82	
92.000		22.5	0.254	0.486	54.55	-54.76	25.19	0	152	84	
93.000		19.5	0.240	0.429	51.27	-46.75	12.07	0	141	99	
94.000		14.9	0.311	0.460	45.5	-28.25	23.95	70	119	65	
95.000		14.3	0.220	0.356	44.66	-34.76	-3.702	0	121	110	
96.000		13.5	0.406	0.433	43.51	-0.946	30.53	117	102	51	
97.000		12.0	0.341	0.372	41.22	-2.756	10.27	99	98	80	
98.000		10.9	0.246	0.390	39.41	-30.34	4.339	14	105	84	
99.000		10.5	0.304	0.374	38.73	-11.8	6.676	75	96	79	
100.000		8.2	0.309	0.357	34.4	-6.497	3.88	72	84	74	
101.000		7.9	0.349	0.381	33.77	-2.448	11.08	82	80	61	
102.000		7.6	0.263	0.434	33.14	-29.35	11.31	18	89	59	
103.000		74.6	0.298	0.333	89.21	-8.646	-1.957	204	229	226	
104.000		74.7	0.295	0.329	89.25	-8.358	-3.856	203	230	229	
105.000		67.6	0.286	0.322	85.81	-9.443	-7.545	187	221	227	
106.000		49.7	0.286	0.320	75.88	-7.717	-7.434	164	192	199	
107.000		42.4	0.241	0.287	71.15	-14.9	-22.98	109	184	214	
108.000		42.4	0.244	0.310	71.15	-22.59	-15.43	99	187	200	
109.000	Cyan	35.3	0.234	0.290	65.98	-18.49	-21.52	85	172	197	
110.000		29.2	0.260	0.316	60.96	-15.31	-10.26	103	156	163	
111.000		28.6	0.257	0.309	60.43	-14.07	-12.37	101	154	166	
112.000		29.1	0.283	0.315	60.87	-5.892	-7.887	128	151	159	
113.000		24.4	0.279	0.313	56.49	-6.36	-8.376	115	139	149	
114.000		23.4	0.284	0.319	55.48	-6.395	-6.245	115	137	142	
115.000		15.3	0.247	0.260	46.04	0.179	-22.36	85	111	145	
116.000		58.0	0.278	0.335	80.74	-18.11	-4.156	156	211	206	
117.000		61.4	0.265	0.301	82.59	-10.37	-17.59	163	213	236	
118.000		50.6	0.268	0.295	76.44	-5.63	-18.09	157	193	220	
119.000		50.4	0.246	0.279	76.31	-9.512	-26.48	134	196	235	
120.000		36.1	0.219	0.267	66.6	-16.78	-30.63	68	173	215	
121.000		24.4	0.195	0.253	56.49	-20.84	-33.36	0	148	191	
122.000		24.2	0.198	0.238	56.29	-13.28	-37.67	0	145	199	
123.000	Blue	12.6	0.177	0.188	42.15	-0.584	-46.68	0	104	175	
124.000		14.9	0.249	0.259	45.5	1.233	-22.24	86	109	143	
125.000		12.9	0.191	0.253	42.61	-18.48	-27.28	0	111	144	
126.000		8.9	0.187	0.195	35.79	0.85	-38.82	0	87	145	
127.000		8.6	0.201	0.208	35.2	1.407	-33.85	33	85	136	
128.000		7.1	0.207	0.248	32.03	-8.609	-22.36	16	81	109	
129.000		5.9	0.223	0.271	29.16	-8.977	-15.79	28	74	92	
130.000		4.0	0.275	0.276	23.67	2.854	-10.18	53	56	71	

Appendix I

The CTC Results of the Color Coordinate, the LAB and the RGB

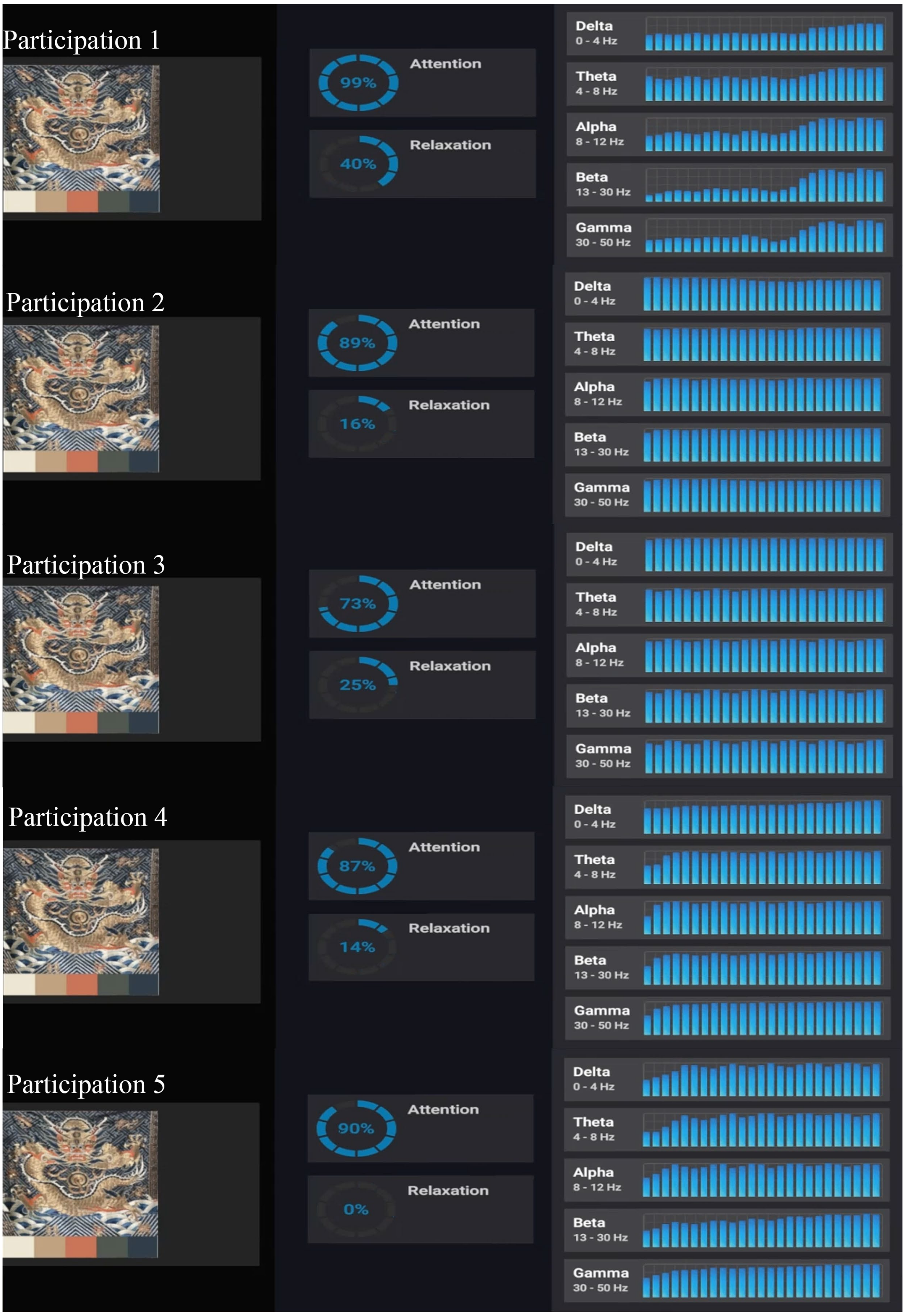
Number Sequence	Hue		Color Coordinate			L,A,B			R,G,B			RGB color visualization
			Y10	x10	y10	L	A	B	R	G	B	
131.000			42.0	0.299	0.299	70.87	6.711	-11.69	176	170	193	
132.000			42.1	0.294	0.282	70.94	12.05	-17.84	181	168	205	
133.000			35.2	0.271	0.259	65.9	11.79	-27.03	156	155	207	
134.000			31.0	0.247	0.245	62.51	7	-33.24	128	150	208	
135.000			29.5	0.283	0.258	61.22	16.57	-24.44	156	140	190	
136.000			29.2	0.263	0.246	60.96	13.55	-30.5	142	142	199	
137.000			23.7	0.302	0.296	55.79	7.66	-10.11	139	130	150	
138.000			21.2	0.293	0.293	53.17	5.344	-11.46	127	125	145	
139.000			12.8	0.242	0.209	42.46	17.36	-35.05	96	93	157	
140.000			6.6	0.301	0.269	30.88	11.47	-11.49	82	67	90	
141.000	Purple		6.0	0.264	0.222	29.41	15.36	-22.88	75	63	104	
142.000			10.4	0.345	0.239	38.55	35.37	-16.46	133	68	117	
143.000			9.4	0.425	0.286	36.74	36.74	1.801	140	60	84	
144.000			8.4	0.371	0.257	34.8	32.94	-9.191	124	60	96	
145.000			7.5	0.320	0.236	32.92	26.71	-17.36	106	62	104	
146.000			7.0	0.300	0.232	31.81	22.46	-19.3	95	63	105	
147.000			8.1	0.361	0.309	34.19	15.6	0.136	104	71	80	
148.000			5.9	0.347	0.269	29.16	21.04	-7.773	95	57	80	
149.000			6.0	0.414	0.309	29.41	23.92	4.554	105	54	63	
150.000			5.3	0.385	0.313	27.57	17.03	2.614	91	55	61	
151.000			4.7	0.306	0.277	25.86	9.433	-8.624	70	57	74	
152.000			47.6	0.434	0.426	74.57	9.47	50.9	226	175	87	
	Golden		52.3b	0.429	0.422	77.46	9.475	49.89	235	183	96	
153.000			39.2	0.462	0.418	68.9	19.2	52.05	224	153	71	
			41.2b	0.460	0.418	70.32	18.95	52.4	228	157	74	
154.000		white	89.0									
155.000			4.0									
156.000			6.0									
157.000			9.0									
158.000			15.0									
159.000			19.0									
160.000			29.0									
161.000			48.0									
162.000			50.6	0.312	0.330	76.44	-0.371	-0.584	187	189	188	
			51.4b	0.312	0.330	76.92	-0.373	-0.588	189	190	189	
163.000			60.0									
164.000			54.9	0.311	0.328	78.98	0.01	-1.393	194	196	197	
			64.8b	0.311	0.329	84.38	-0.428	-1.134	209	211	211	

Appendix II Brain wave results of cases of chapter 4.

Brain wave results of case one.

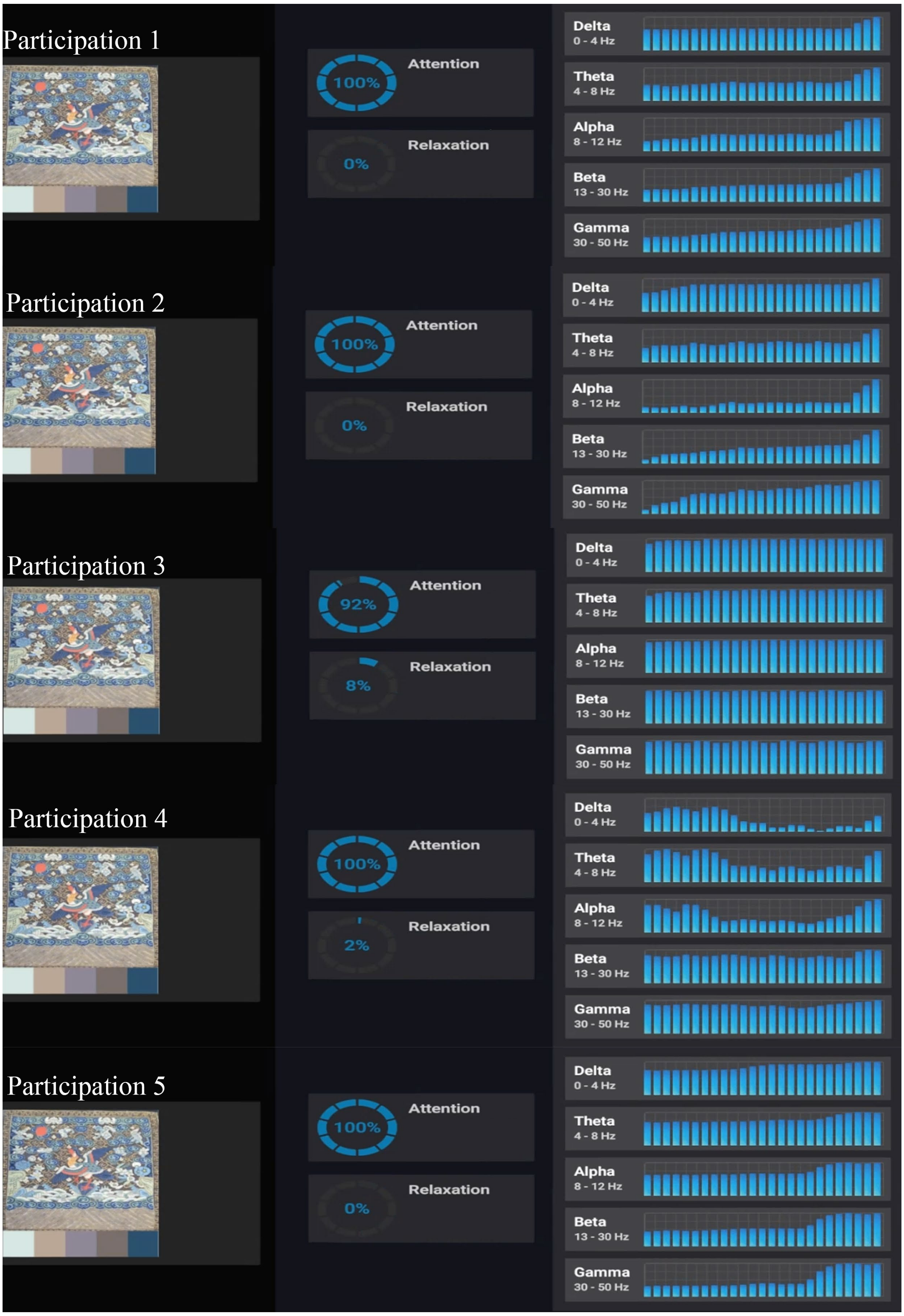
Appendix II

Brain wave results of case two.



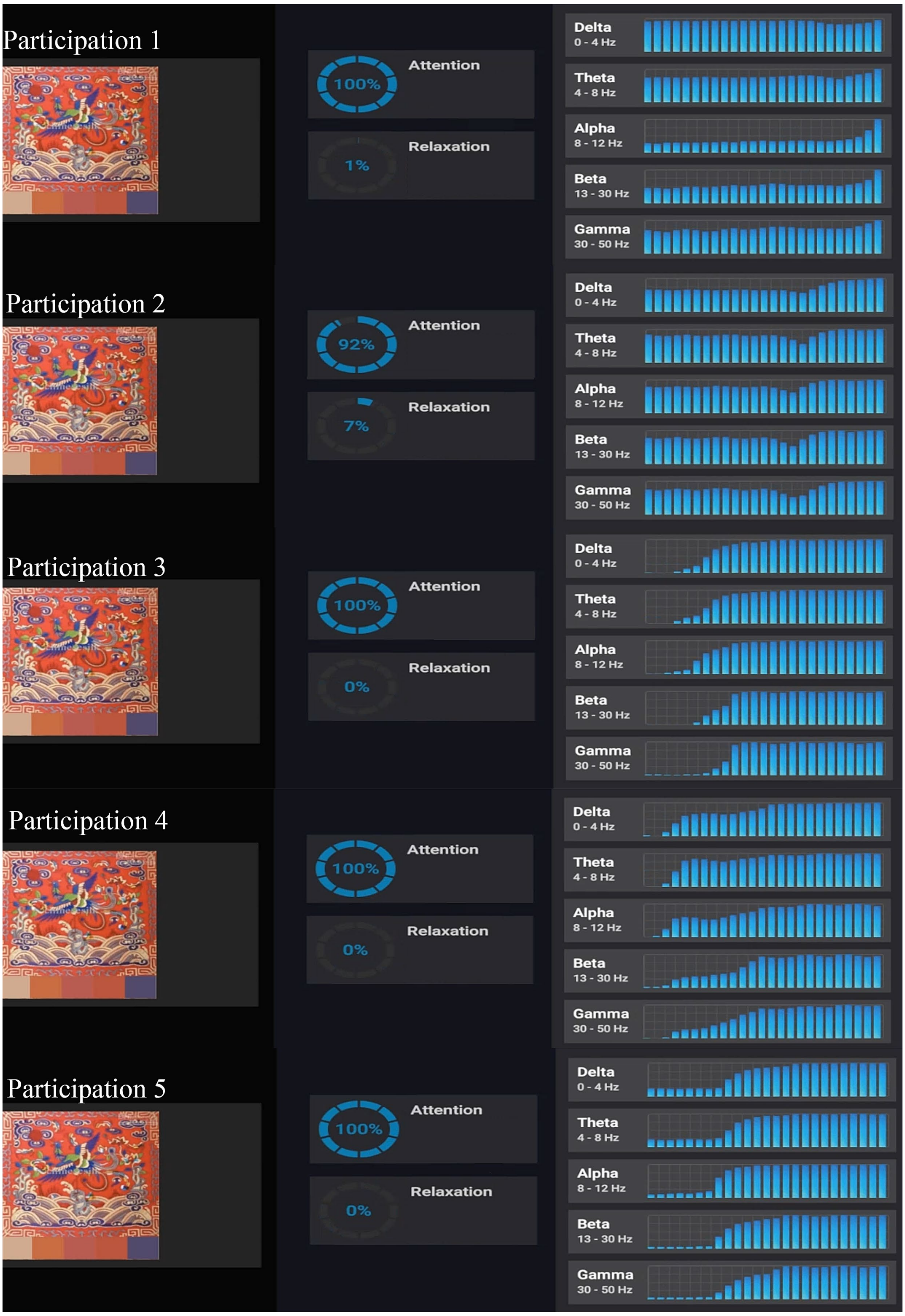
Appendix II

Brain wave results of case three.



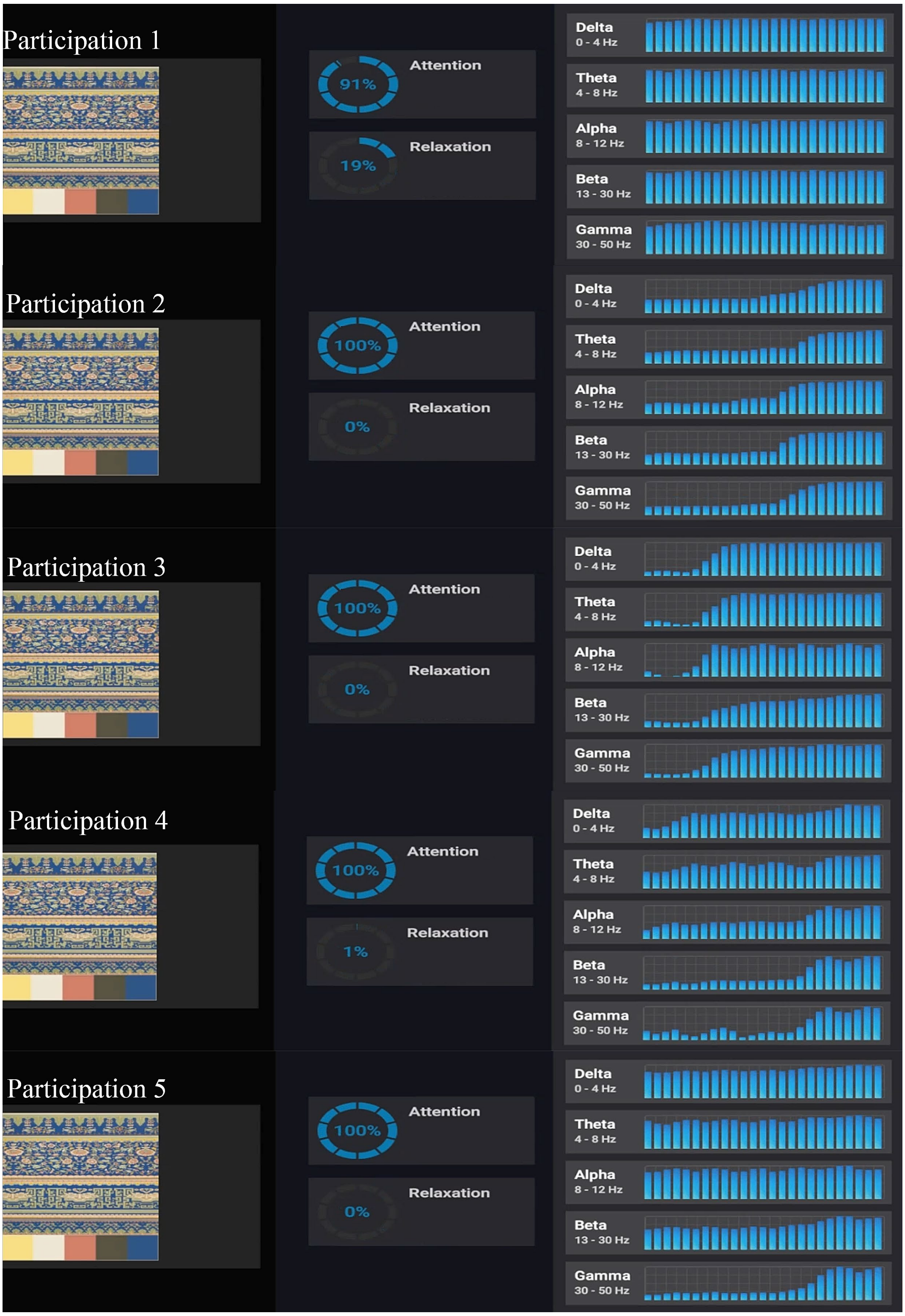
Appendix II

Brain wave results of case four.



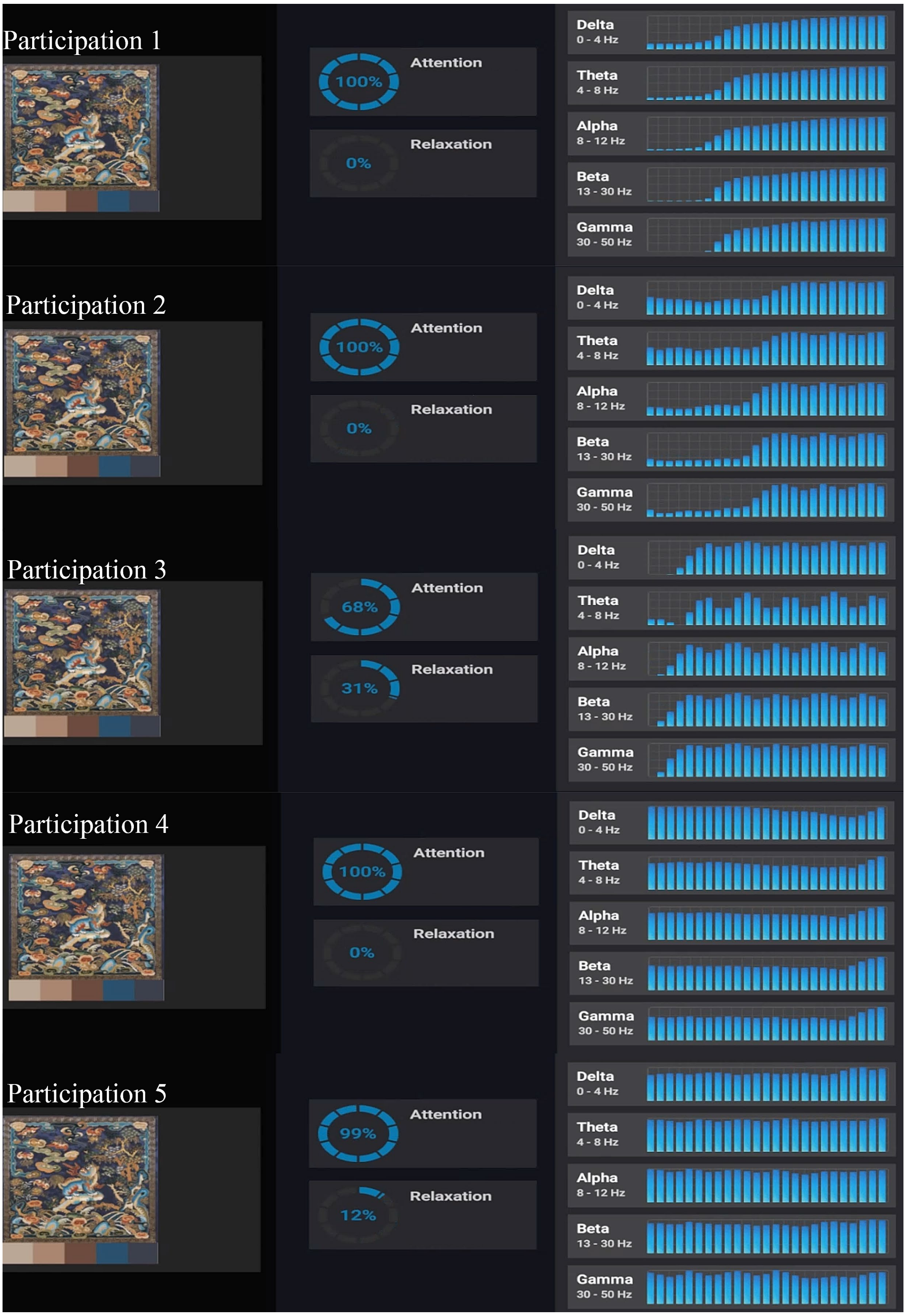
Appendix II

Brain wave results of case five.



Appendix II

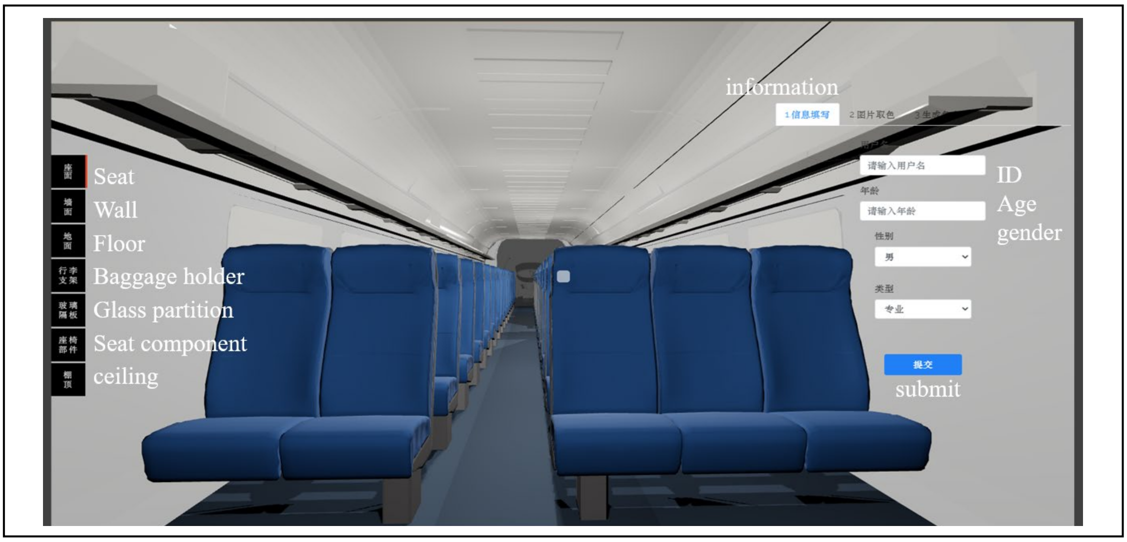
Brain wave results of case six.



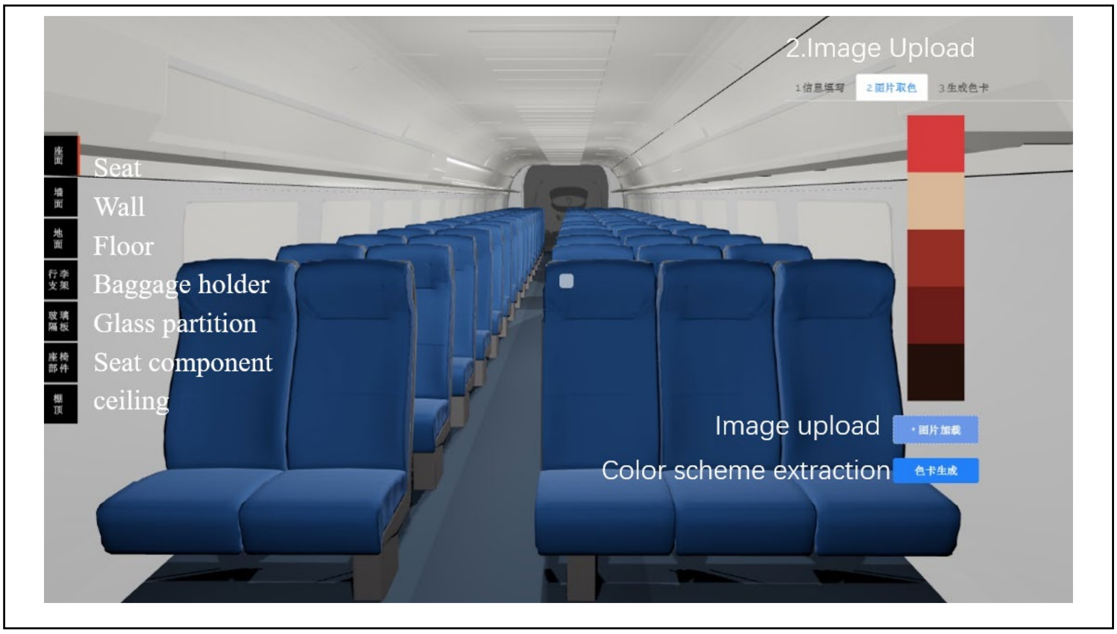
Appendix III The Instructions of chapter 6

Please log in to the following website to connect. The interface load time will take about 2 minutes. After loading successfully, you will see the interface as follows. The operation of the interface is mainly controlled by the mouse, press, and hold the left mouse button, rotate the interface in three dimensions, and adjust the viewing angle by the middle mouse button.

The Website Link: **114.55.166.12:23225/autocolor/index.html**



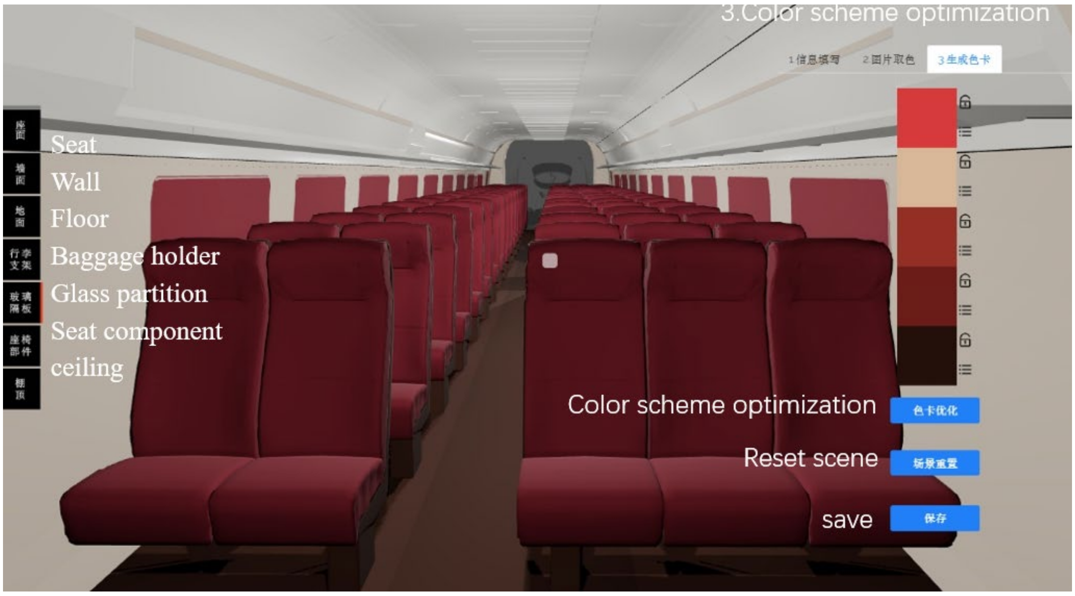
The specific process of the experiment is as follows: (please follow the process steps) the First step, please fill in "**1. Fill in the information in the label**". In the "user name", you only



need to fill in pinyin or initials (please do not use Chinese). In Type, choose according to whether you have relevant aesthetic or design professional background. Finally, the submission will be made, and there will be a prompt on the interface after the submission is successful.

Step 2, please click "**2. The "Picture Color**" tab requires you to select a photo with your favorite color (please select from the range of pictures provided to you) and click the "Picture load" button to upload the photo. After uploading, the current color swatch will change according to the color information in the photos you uploaded (the time consumed will depend on your network speed, please wait patiently and then operate after the color swatch changes).

Step 3, please click "**3. Generate color card tag**", the system will generate a color card according to your uploaded image, if you are not satisfied with the current color, you can click the "**color card optimization**" button. The system will match the uploaded image color to generate "the new" Chinese traditional color scheme. If you do not like the color palette, you can return to "2. Click the generate color card button in the picture color extraction tab" to restore the color swatch.



In the fourth step, you can click the label on the left side of the screen, when the label is selected, the edge of the label will turn red, and then you just need to select different parts of the railway space, and then match the color through the right color swatch (please use the 5 colors in the color swatch). Finally, when you are satisfied, please click the "**Save**" button (everything can be modified before clicking the Save button).

Finally, thank you very much for your assistance.

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