Digital Design of Peking Opera Facial Makeup Based on Facial Emotion Recognition

Siyu Huo [1, a], Yudi Sun [1, b, *], and Jing Zhao [1, c]

[1] School of Art and Design, Beijing University Of Technology, Beijing, China.

[a] gusixian0426@163.com, [b] 15611698199@163.com, [c] zhaojing_milan@163.com

Abstract. This study examines digital technology and cultural innovation in the context of non-genetic inheritance. Traditional digital survival approaches limit public participation and innovation dynamics. To this end, we propose an interdisciplinary approach that combines deep learning and affective computing. Specifically, we develop a CNN-based Peking Opera facial make up synthesis system to achieve intelligent deconstruction and restructuring; construct a model to match users' facial features with opera lines to generate personalised facial make up schemes; and establish a quantitative emotion assessment system using Python to achieve a dynamic correlation between expression capturing and face elements. The method enhances public interaction and broadens the influence of Peking Opera facial make up communication. The study confirms that the 'digital empowerment + public participation' model can promote the sustainable inheritance of intangible cultural heritage, use intelligent technology to bring users closer to traditional culture, and provide a replicable technical paradigm for the digital presentation and innovative development of traditional culture in the intelligent era.

Keywords: Peking Opera, intangible cultural heritage, Intelligent Technology, Deep Learning Algorithms, Peking Opera Facial Makeup Innovation.

1. Introduction

1.1 Research Background

Intangible cultural heritage (ICH) is an important part of Chinese culture, carrying rich historical memory and national emotions. However, with the acceleration of modernisation, traditional culture is facing the challenges of faulty inheritance and limited dissemination channels[1]. As one of the important symbols of ICH, Peking Opera facial make up not only has high artistic aesthetic value, but also contains deep cultural connotation and historical value. How to use modern technology to empower the protection and dissemination of ICH, so as to make it more relevant to contemporary society and public life, has become an important topic of current ICH research.

Peking Opera facial make up is a symbol of Chinese opera culture, which expresses the character, identity and emotional characteristics of the characters through rich lines, bright colours and complex patterns. This highly programmed expression is not only a visual art, but also a metaphorical cultural expression[2]. Through the digital design of facial make up, its cultural symbols can be analysed more systematically to promote its inheritance and dissemination.

With the rapid development of artificial intelligence technology, facial recognition technology has become an important direction in the field of computer vision. Through deep learning algorithms, facial recognition technology can not only accurately capture facial features, but also quantify the emotional state by means of micro-expressions, motion capture, etc.[3], which provides new possibilities for the combination of cultural and creative industries and non-genetic inheritance. In recent years, breakthroughs in deep learning algorithms such as convolutional neural networks (CNN) and recurrent neural networks (RNN) have led to significant improvements in facial expression recognition rates, achieving high-precision emotion classification and recognition based on facial keypoint detection, image feature extraction and temporal analysis[4].

Facial recognition technology is widely used in mental health monitoring, intelligent interaction, entertainment and education. For example, in the film and game industry, emotion recognition technology is used to achieve facial and dynamic expression generation for virtual characters[5]. In the field of user experience optimisation, more accurate product design and service customisation can be achieved by capturing users' real-time emotional feedback.

1.2 Research Significance

In recent years, intangible cultural heritage (ICH) has received more and more attention, and its promotion is often combined with tourism , appearing in museums and humanities attractions in the form of interactive products. 'ICH+tourism' is a vivid practice of shaping tourism with culture and highlighting culture with tourism[6]. Through the combination of modern technology, ICH has more and more opportunities to be pushed to a wider user group and increase the audience of ICH, so that users of different ages and social strata have the opportunity to learn about ICH through a diversified, multi-faceted, and sufficiently in-depth way, and then join the inheritance of intangible cultural heritage and protection.

This study will also make innovative contributions to related technologies. According to the results of the preliminary research and user observation, many users said that although they have a certain understanding of ICH through publicity, they still have a strong sense of distance from ICH. Therefore, at the user level, our research can increase the depth of users' knowledge of ICH and deepen their understanding of intelligent identification and generation technology during the interactive experience while helping to protect ICH. At the technical level, the innovation of this research lies in the study of digitally redesigning existing ICH, giving modern technology the connotation of traditional culture, and presenting Peking Opera facial make up to the public in an innovative way that is closely related to the user.

1.3 Literature Review

Today's world has gradually entered the digital era, with the booming development of digital technology and digital intelligence, as a new way of cultural and digital consumption, showing a strong demand[7]. At present, museums in the process of intangible cultural heritage protection, the use of digital technology means to store and build management systems for all-round collection of relevant data and information of collections[8]. However, in terms of human-computer interaction devices with low sensitivity, difficult to generate complex personalised customised solutions, low innovation leads to low user satisfaction and other optimisation issues.

Existing physical interactive devices and APPs for the purpose of traditional culture dissemination are mostly based on information display, and users mainly rely on observation to obtain information. This kind of information interaction mode is relatively single, which users passively accept the knowledge[9] with a low sense of participation, causing the difficulty to get an immersive experience.

Technical level, the current facial expression recognition is mainly based on deep learning technology and convolutional neural networks, widely used in high-tech industries such as intelligent robots[10]. The most important part is feature extraction, deep learning models can automatically extract features to cope with complex interference factors. Also new models have been continuously developed to improve the accuracy of expression classification [11].

Despite certain difficulties, combining the digitisation of NRM with the cultural and creative fields and carrying out co-creative activities has the dual value of broadening the audience and obtaining economic benefits[12]. At present, in the field of ICH protection, digital technology is mainly applied to storage and restoration[13], and there is still a certain gap in the protection and inheritance through interactive devices, and the interactive mode and technology application issues need to be further discussed.

Comprehensive the above status quo, this paper through the study of ICH digital redesign of innovative ways, so that the user in the interactive experience process through personalised

customised services on ICH initiative to generate curiosity, pulling into the distance between the user and the traditional culture, to explore the possibility of human-computer interaction for the form of innovation.

2. Research Content

2.1 Innovation points

This project combines non-genetic inheritance with modern technology, using computer technology to arrange and reorganise facial scores, so that the non-genetic inheritance of Peking Opera facial scores is ‘alive’, more varied and full of vitality.

Adopting the method of ‘personalised customisation’, using facial capture and emotion recognition technology to identify the user's gender, age, emotion and facial features, and using the code to quickly generate the user's ‘exclusive’ facial make up, which can effectively narrow the distance between the user and the heritage, and increase the understanding of the heritage. This can effectively narrow the distance between the user and the ICH, increase the interest in the ICH, and also further promote the knowledge of the ICH.

Adopting the method of emotion quantification, the emotions are broadly divided into six basic types, firstly, the facial make up is disassembled into different parts, and then different emotion values are assigned to various forms of the same part of the facial make up in the database; after the facial capture device collects the user's data and analyses the data, the different categories of emotions are assigned objective values according to the above assignment criteria, and the values obtained from two analyses are compared, so as to filter the values that are the most similar to each other. The values obtained from the two analyses are compared, so as to filter the random combination of faces with the most similar values, which is finally presented to the user.

2.2 Research ideas and methods

2.2.1 Research framework and technical lines

The overall idea of this project is to combine the ICH with modern technology, use modern technology to help revitalise the ICH, and inject the cultural connotation of the ICH into modern technology in order to inspire new use scenarios of modern technology.

Firstly, we collect references to understand the current research status of this project, to understand the market application of ICH revitalisation design, to investigate whether users have in-depth understanding of the ICH of Peking Opera facial make up and the degree of understanding, satisfaction and demand of users for the current digital design. This project carries out an in-depth study of Peking Opera culture and facial make up symbols, systematically analysing the symbolism and cultural background of Peking Opera facial make up with the help of cultural, artistic and historical methods[14]. Through cooperation with Peking Opera professionals, in-depth understanding of the roles and cultural connotations of different faces in traditional performances. The above information was collected and summarised to determine the positioning of this project as an innovative research on the digital redesign of facial make up and personalised customisation of facial make up.

Next, the Peking Opera facial make up is disassembled into different parts for easy arrangement and combination, and then the facial expression, gender and age are converted into digital signals, and how different parts can be arranged and combined and then output after being converted into digital signals, etc. The code is written.

Afterwards, the available plug-ins for facial capture devices are obtained through data collection and integrated with the previously written code to form a complete set of procedures, which are combined with intelligent learning algorithms and big data analysis to establish a personalised user customisation model. Through user surveys and practical applications, the algorithm is optimised to provide more accurate and personalised facial make up design suggestions.

At the same time for the user interface design, combined with the results of the preliminary research, to understand the user needs and pain points, targeted to the use of the interface UI design. Through prototype testing and user feedback, we continue to iterate. Integrate social media functions and design user-friendly interactive interfaces to promote sharing and interaction among users

2.3 Research methodology

2.3.1 Emotional quantification techniques

We use six basic emotion classifications - pleasure, sadness, anger, surprise, fear, and calmness - to define the performance characteristics of each emotion based on theories related to emotional psychology and Peking Opera. These six emotions are quantified according to the characteristics of different face elements, and the quantified values are assigned to different parts of the split face elements.

The main technical realisation is as follows: firstly, the classic Peking Opera facial make up samples are selected, and the features of the five senses, such as eyebrows, eyes, nose and mouth, are extracted; secondly, combined with the relevant theories, the emotion values are set for the five senses of different forms. For example, raised eyebrows may indicate surprise or excitement, narrowed eyes may indicate anger or suspicion, and upturned corners of the mouth represent pleasure or friendliness. For example, in the Peking Opera excerpt ‘Single Sword Club’, according to the character traits of the character's courageousness and loyalty and the comprehensive analysis of the plot, the character's eyes highlight the majestic and solemn emotion, so ‘anger’ is assigned a higher quantitative value. Therefore, ‘anger’ is assigned a high quantitative value.

2.3.2 Face expression recognition techniques

We obtain the user's facial expression changes and use emotion recognition algorithms and deep learning techniques to analyse the user's facial micro-expressions and expression dynamics to extract emotional features.

For software and hardware devices, we captured the user's facial expressions in real time by deep learning models (e.g., Convolutional Neural Network CNN) with facial recognition devices, a step that relies on facial muscle action units to analyse and accurately capture the characteristics of the human facial muscle groups. For the user's facial information entered into the programme, we extract key features of the five senses, such as the curvature of the eyebrows, the degree of opening and closing of the corners of the eyes, and the degree of upward and downward movement of the corners of the mouth. These facial expression features are converted into specific feature parameters with the support of algorithms, which serve as the basic data for emotion analysis.

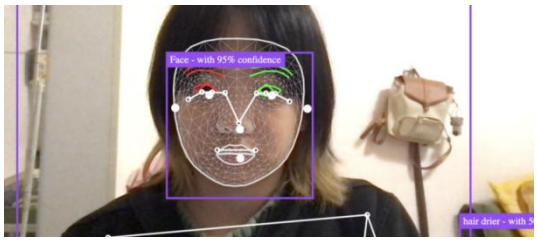

Fig. 1 Example of user facial expression input

2.4 Digital Redesign of Peking Opera Facial Make Up

2.4.1 Extraction of Design Elements of Peking Opera Facial Make Up

The flat spectral features of Peking Opera facial make up are mainly distinguished by the different colours and patterns painted in different areas of the face. Such as the ‘three tile face’ eye-brow lines from the forehead into the sideburns will be divided into three pieces of the face,

positive and negative characters can be represented; another example is the ‘butterfly face’ face like a butterfly, on behalf of the image of the bright and upright.

The area of the facial make up is usually divided into three blocks, with the forehead eyebrows as a group, eyes, upper and lower eyelids, wrinkles as a group, nose, lips and cheeks as a group, the facial emotions expressed are closely related to the action characteristics of these three blocks. For example, the upper eyelids are raised when sad, and the jaw drops down opens when surprised[15].

In summary, we can obtain the typical features of different parts of the elements in the facial make up in expressing different facial expressions, and the more samples of faces with typical features have been split into face elements, classified and reorganised by splitting according to the eyebrow, eye, forehead, nose, mouth and chin.

There are more samples, and some of the split single samples are shown in Figure 2 below.

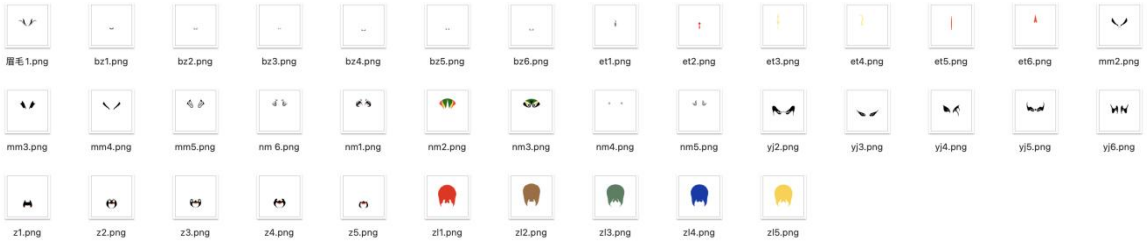

Fig. 2 Peking Opera facial make up elements drawn after partial disassembly

2.4.2 Emotion quantification results

Based on the above research methods and known literature, we quantified and analysed the samples. Combined with the traditional symbol system of Peking Opera facial make up, this study adopts the emotion quantification method based on expression recognition to numerically quantify the Peking Opera facial make up according to the features of the five senses, and the specific assignments are shown in Figs. 1-6 below.After completing the emotion assignments of individual five senses, the recognition is used to process and synthesise the whole face, and due to the different impacts of different senses on the emotion, we introduce the weight coefficients (e.g., the eyes are weighted at 0.4, the brows at 0.3, and the mouth at 0.3), and comprehensively calculate the final face emotion value. , mouth weight 0.3), and synthesise the final face emotion value.

Some samples are analysed in Tables 1-6.

Table 1. Eyebrow elements

眉毛 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	1	0	1	2	0	1
	1	1	0	3	1	0
	1	0	1	2	0	1
	2	1	1	1	0	1
	0	2	1	1	0	3

Table 2. The nose element

鼻子 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	1	3	2	1	0	2
	1	2	1	1	0	3
	1	2	2	3	0	1
	2	0	1	0	3	1
	3	2	1	0	1	1

Table 3. Head elements

Table 4. Forehead elements

头 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	1	1	0	1	3	0
	1	2	1	1	0	2
	1	1	2	3	1	0
	1	2	3	1	0	1
	0	2	1	1	0	3
	2	1	2	3	0	1

额头 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	1	1	2	1	0	1
	1	0	3	2	1	1
	2	1	1	3	0	1
	1	2	3	1	0	1
	3	2	1	1	0	2
	1	1	0	0	2	1
	2	1	1	3	0	1

Table 5. Chin elements

下巴 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	0	2	2	3	1	1
	3	1	1	0	2	1
	1	3	2	0	2	1
	2	1	0	0	3	1
	0	3	2	1	0	1

Table 6. Eye elements

眼睛 / 情绪数值	惊奇	恐惧	厌恶	愤怒	高兴	悲伤
	1	0	1	2	1	1
	2	0	2	3	1	0
	1	1	2	3	1	0
	1	3	2	0	0	2
	1	2	3	2	0	1
	1	0	2	3	1	1
	1	2	3	1	1	2

2.4.3 Personalised Peking Opera Facial Make Up Design

Building on the quantitative analysis of emotions, we used the extracted Peking Opera facial makeup elements and quantitative data to develop a further "personalized" facial makeup design. This customization is achieved by mapping emotional data to the reorganization of the five facial features, allowing for the tailored generation of unique designs.

Based on the user's emotional input, we combine the five facial features to generate a personalized Peking Opera facial makeup. Using emotion calculations and programmed algorithms, we create a makeup design that matches the user's facial features and emotional state. For example, with anger (value 3), the design features downward-pressing eyebrows, rounded eyes, and a downward-slanting mouth; with pleasure (value 2), it includes spreading eyebrows, upturned eyes, and a smiling mouth; and with sadness (value 3), the design features downward-pressing eyebrows, slightly downward-slanting eyes, and a sad mouth. This logic allows us to generate static faces based on emotions. Additionally, expanding user input enables the system to learn and adapt, adjusting the facial makeup details according to the user's emotional changes.

The user's facial information input by the program corresponds to the face symbols, and the complex emotions are presented in a hierarchical and externalised manner through this mapping mechanism. This recombination of fixed symbols with dynamic expressions gives Peking Opera facial make ups more emotional depth, while increasing the user's engagement with the art of Peking Opera.

3. Design Practice

3.1 Preliminary Research Results

In response to the understanding and future expectations of products related to Peking Opera facial make up, we developed a questionnaire with a total of 12 questions, including 6 single-choice

questions, 5 multiple-choice questions, and 1 sorting question, and finally received a total of 122 responses.

According to the personal information, nearly half of the respondents were between the ages of 18-25, and another 42% of the respondents had a bachelor's degree in education.

Survey data shows most respondents learn about Peking Opera through TV, social circles, and practice (Fig. 2). The key challenge in its inheritance is the lack of innovation (67.21%, Fig. 3), with reforming inheritance methods and enhancing public education as top priorities (Fig. 4).

Regarding cultural and creative works related to Peking Opera facial makeup, about half of the respondents have only heard of them but never engaged (Fig. 5). Interest in personalized interaction is high (71.31%, Fig. 6). Among AR/VR users, the biggest issues are low participation (74.61%) and lack of memorability (54.67%, Fig. 7).

Fig. 2 Channels through which respondents usually learn about Peking Opera

Fig. 3 Challenges to Peking Opera's legacy as perceived by respondents

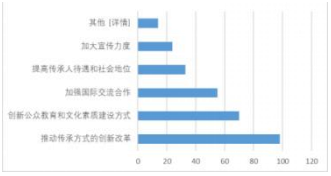

Fig. 4 Effective measures to solve the inheritance problem of Peking Opera

Fig. 5 Whether or not they have used facial make up related promotional products

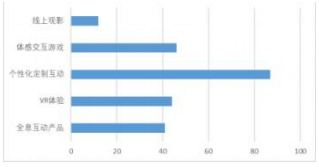

Fig. 6 What modern forms of publicity would you like to experience with facial make up

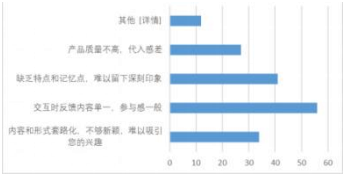

Fig. 7 What points of improvement could be made to the current product

After the questionnaire research, we agreed that in order to improve the inheritance of ICH such as Peking Opera facial make up, we need to start from the innovation of the publicity form, to enhance the sense of participation and immersion in the user experience, so as to give the user a deep sense of memory, and then to achieve the purpose of popularisation and promotion of ICH.

3.2 UI interface design

The UI design clearly visualizes the process from facial expression recognition to face generation, highlighting the one-to-one mapping between expressions and facial features. Step-by-step guidance ensures clarity, while additional features provide opera knowledge and an online community for cultural engagement.

The start page (Fig. 8) features the APP logo with a red-and-white theme, inspired by the eyes and eyebrows of Peking Opera makeup—both core artistic elements and key emotional indicators. The personal homepage (Fig. 9) allows users to review their customized facial makeup history and manage personal settings.

Fig. 8 startup page

Fig. 9 Personal Home Page

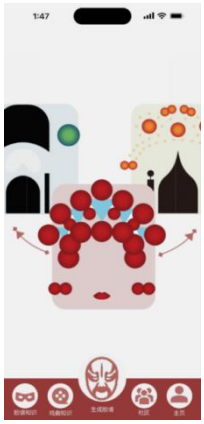

Fig. 10 type selection page

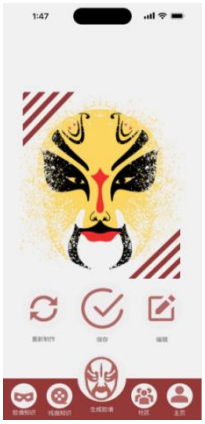

Fig. 11 AI facial make up generation page

Fig. 12 popularization page

Fig. 13 community page

Character type selection page(Fig. 10): five large icons are used to represent the five major character types of “Sheng”, “Dan”, “Jing”, “Mo” and “Chou” respectively, with five icons used as representation. Each icon visualizes the characteristics of the character, such as the classic costume of the character. When clicking on the character icon, select the character and start generating process.

Facial make up Generation Page(Fig. 11): Users input basic information like gender, age, and mood. AI processes this data to generate a personalized facial makeup design based on emotions and demographics. The page allows users to regenerate, save the result, or edit individual elements.

Opera Knowledge Page(Fig. 12): Engagingly spreads Peking Opera culture, character analysis, and emotional expression, showcasing its history, characteristics, and significance.

User community page(Fig. 13): encourages communication among users and promotes the dissemination and learning of Peking Opera culture by re-sharing their facial make up works, Peking Opera viewing experience or learning records.

4. Discussion

4.1 Design Validation

After completing the design, five users tested it and were interviewed. Overall, they found it novel and exciting to see facial makeup generated from their expressions. One noted the clear step-by-step instructions and satisfying results, while some felt subtle expression recognition needed improvement. Despite this, users were surprised by the technology’ s performance, with some stating it effectively promoted ICH culture and deepened their understanding of facial expression categorization and significance, saying that ‘after this experience, I have gained a better understanding of the categorisation and significance of the facial expressions’.

4.2 Existing problems and deficiencies

In the case of insufficient precision of the current technology, the details of facial capture are not precise enough, and emotional misjudgment may occur leading to matching bias. The system-generated facial make up does not match the user's real emotions, which may trigger the user's dissatisfaction and reduce the immersion and trust of the interaction.

For this problem, we have added a feedback mechanism that allows users to manually adjust the facial expression matching degree based on the results after the initial generation. In addition to the situation of technological progress, we will also consider adding multimodal measurements in the

future, and introduce more modal data (e.g., voice tone, heart rate measurements, etc.) to merge with the facial capture data, so as to improve the accuracy of the system.

4.3 Future Prospects

Future research can explore integrating facial makeup generation into practical scenarios such as education, cultural tourism, virtual socialization, and art exhibitions to expand NGT’ s reach and audience. This not only enhances the modern value of traditional culture but also fosters deeper engagement with ICH through technology.

In cultural tourism, facial recognition in museums can personalize exhibitions by analyzing visitors’ expressions and adjusting content accordingly. Integrating VR can further enhance interactivity and immersion. Coupled with emotion recognition, facial makeup generation could become an innovative form of museum cultural creation, driving the integration of museums with technology and offering audiences a more personalized and intelligent cultural experience.

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