Sustainable AI Design for Canton Embroidery Based on Design Thinking an Example of Lotus and Butterfly Themes

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Abstract. Canton embroidery is one of China's intangible cultural heritages, and its designs reflect the "fusion of East and West" in Lingnan Region of China. In the trend of applying artificial intelligence to the development of traditional crafts, research on the application of artificial intelligence to Canton embroidery is lacking in order to conclude the sustainable development of digitization. This study examines the viability of incorporating AI painting into Canton embroidery by developing a functional model of AI painting design based on the digital database of team Canton embroidery. The model consists of four stages: (1) Developing a project via fieldwork and literature evaluation (2) exercising AI painting application in five aspects, including theme, color, style, composition, and atmosphere (3) Customer Satisfaction Index assessment of model outputs by youth groups and broad embroidery practitioners, and internal consistency. The working model of AI drawing design can provide new ideas for the evolution of embroidery, distinguish it from other forms of modern embroidery, and serve as a case study for the integration of AI with traditional craftsmanship.

Keywords: AI painting, intangible cultural heritage, Canton embroidery, design thinking, sustainable development.

1. Introduction

Canton embroidery is one of China's intangible cultural heritages and was included on the first set of China's national list of intangible cultural heritage (No. VII-20) in 2006. The only embroidery production company in Guangzhou (Guangzhou Embroidery Craft Factory Co., Ltd.) employs fewer than ten embroidery artisans, all of whom are over the age of 35 and have spent at least eight years in the embroidery industry. Although the Guangzhou government has attempted to promote the development of Canton embroidery, the initial scarcity of practitioners, the lengthy training period for embroidery craftsmen (a mature embroidery craftsman must be trained for more than five years), and the high cost of the paintings make Canton embroidery works generally costly, making widespread transmission and application difficult.

Along with the development of computer disciplines, embroidery research methods have shifted from field survey methods and pictorial methods to big data and artificial

intelligence to investigate the application of robotics and AI technologies in the field of embroidery. Chung-Feng Jeffrey Kuo et al. A probabilistic neural network-based, texture-fitting approach to visually simulate the real effects of embroidery [1], Zhao and other scholars analyzed the artistic features of Xiang brocade in terms of patterns, color schemes and techniques, and based on this, introduced AI to complete feature extraction and state classification to achieve the purpose of digital conservation of Xiang brocade [2]. AI is presently used less frequently in the actual production of embroidery, but it does provide new opportunities for preserving and revitalizing traditional arts and crafts. Scholars such as Ioannis Rallis use machine learning to capture, document, and store dance movements in intangible cultural heritage, as opposed to the previously prevalent method of filming and recording[3]. Yehang Yin uses the glyphs generated by deep learning to assist users with no seal carving experience in completing their own seal designs and obtaining a physical seal carving artwork rapidly[4]. Scholars such as Theodora Pistola develop web platforms to digitally preserve intangible cultural heritage, offering online resource searching and utilizing technologies such as VR and AI to analyze ethnic dances and texts for innovative applications of intangible cultural heritage[5]. Zhang employs the GANs model to analyze the New Year prints and the K-means algorithm to extract the color and colorize the prints from the Pop Art dataset in order to generate New Year prints with a Pop Art aesthetic[6]. The aforementioned application of AI in traditional crafts provides a reference for the combination of Canton embroidery and AI, but there is currently no survey on the popularity of traditional crafts created by combining AI to evaluate the appeal of traditional crafts combined with AI. Consequently, it is of practical importance for this study to attempt to incorporate AI into the actual production of Canton embroidery.

We attempt to propose an AI painting training model for embroidery design and introduce Midjourney, a convenient AI painting system for embroidery design, which enables many users who are not skilled at painting and design to generate their own satisfactory works using text and image resources, which is in line with modern technology and not limited by traditional human thought, and provides more design creation options. It also mitigates the decline of Canton embroidery practitioners and expands the consumer base and audience to a certain extent. Through the participation of Chat-GPT, social groups, and design practitioners, this study selects AI paintings that are applicable to Canton embroidery, uses human-computer design to enrich the Canton embroidery gallery, lowers the creation threshold of Canton embroidery drawing design, and facilitates printing and printing products (bookmarks, notebooks, postcards, silk scarves, etc.), small accessories (brooches, makeup bags, pendants, etc.).

2. Method

2.1 Design Thinking process

Traditional processes for formulating strategies are analytical, linear, problem-centric, and retrospective. They intend to capitalize on what is known by employing analytical and quantitative methodologies. Design thinking, on the other hand, prioritizes real people and emphasizes the significance of exploring the unknown[7] and aligning individual objectives around a common outcome through team interaction[8]. In 2005, the British Design Council

introduced the Double Diamond model, which combines divergent and convergent thinking with step-by-step explanations and can be used as a more accessible simplification of the d.School's five phases of design thinking. The process paradigm for this study is based on the design thinking double diamond approach and its derived design thinking for strategy ("DTS") design thinking model (Figure 1). In accordance with the two current development goals of Canton embroidery, which are the need to differentiate it from other embroideries and its sustainable application in a modern society to attract younger groups, and based on its human-centered requirements, the opinions of various groups can be incorporated into the study.
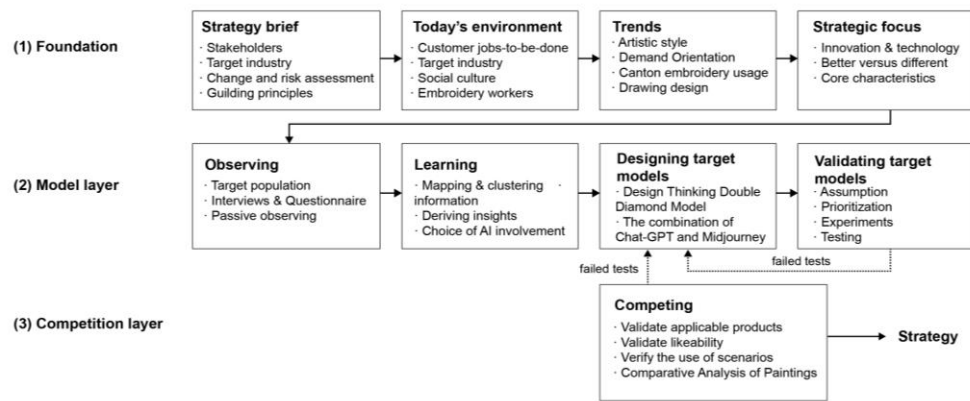

Fig. 1. Research Framework.

2.2 Questionnaire development

1) Questionaire development: In the 2022 ICH Consumption Innovation Report, Ali Research Institute revealed that the number of ICH stores on Taobao was 32,853, the transaction value of ICH increased by 11.6% compared with 2020, and the scale of consumers of ICH goods reached one billion, with the age concentrated in the post-90s and post-00s[9], and the young group has become the primary consumer of ICH cultural products and the primary focus of the research. The questionnaire was distributed twice, and the first questionnaire set a total of 12 relevant questions, including single and multiple choice questions, based on the reality of field research, and the questions were all closely related to the topic, and the purpose of its setting included: determining whether the respondent was a suitable research target, the respondent's knowledge of Canton embroidery, the respondent's willingness to introduce AI into Canton embroidery production, and whether they believed that AI would improve Canton embroidery production.

The survey's objective is to conduct preliminary research that does not involve sensitive or private data.The second questionnaire mainly asked about the tendency of drawing application and Customer Satisfaction Index(CSI). CSI is a comprehensive evaluation index of the level of satisfaction of representative customers of various types and levels, used to forecast industry trends influenced by changes in customer satisfaction [10] .

It should be noted that these are two anonymous questionnaires that do not require the completion of names and units, thereby ensuring that the research information acquired is more accurate and reliable, and that they will be distributed for one week. The first questionnaire

received 211 valid completed questionnaires, and the second questionnaire received 239 valid completed questionnaires. The research population comprised of 1) non-embroidery social groups, 2) students who had attended embroidery training classes, and 3) embroidery industry workers in order to obtain accurate and detailed data and content from a variety of perspectives.

2)Midjourney painting model workflow combined with Chat-GPT: The overall workflow of this study is divided into four stages based on prior research. The first step is to collect colour data based on field research with a Deta colour picker, identify common themes in extant Cantonese embroidery works, and use the paintings of the renowned Lingnan painter Ju Lian from the Qing Dynasty as a sample for analysis. In the second phase, Chat-GPT will extract keywords from Theme, Colour, Style, Atmosphere, and Composition based on the paintings, after removing repetitive or incorrect keywords, and create an initial database of Cantonese embroidery utilising artificial intelligence. The third stage is to select and combine the keywords from the five perspectives, and to choose the user's prefered Ju Lian painting as the reference sample for comparison. Individual paintings are output through Midjourney to conclude the human-computer collaborative design in the third step. Lastly, the generated drawings choose the production method independently, and if embroidery work is required, the embroidery experts will evaluate and determine whether it is appropriate to produce satisfactory drawing design work. (Figure 2).
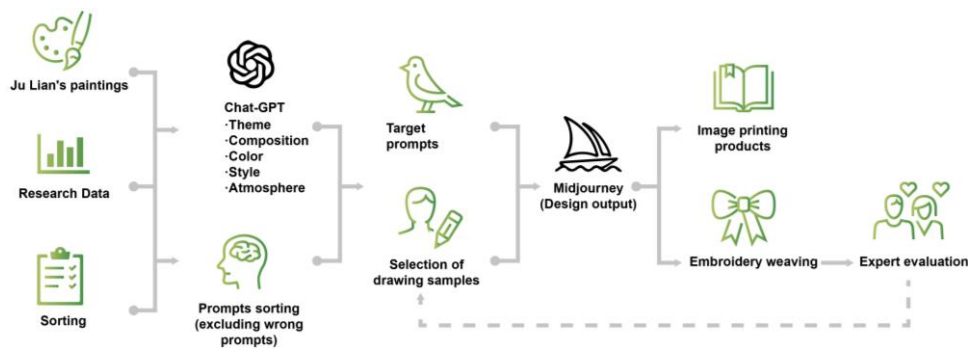
Fig.2. Workflow.

3. Results

3.1 Pre-research

The preliminary research consisted primarily of a questionnaire survey of 211 non-embroidery industry consumers and an initial semi-structured interview at Guangzhou Embroidery Craft Factory. The Cronbach's alpha coefficient of the questionnaire was 0.853 and the value of KMO was 0.902, $p < 0.05$, with good reliability and validity. Only 6.16 percent of consumers over 30 were willing to embrace the introduction of AI into embroidery, and 9.55 percent were willing to spend money on it, and acceptance of AI decreased with age (Table1).

Table 1. Preliminary Investigation on the Consumption Impact of Introducing AI Painting in Cantonese Embroidery.

		Q5. Willingness to buy due to AI?				
		Under 18	18-25	25-30	30-35	Over 35
Yes	Frequency	15	67	63	12	1
	Percentage	100%	100%	91.3%	28.57%	5.56%
No	Frequency	0	0	6	30	17
	Percentage	0%	0%	8.7%	71.43%	94.44%

We conducted the first semi-structured interview with practitioners in order to interpret the results of the preliminary questionnaire. Currently, middle-aged and elderly people are the most reliable consumers of Cantonese embroidery, and they will only purchase exquisite wall paintings that cost more than 10,000 RMB and require both embroidery artisans and renowned painters to maintain their value. If AI is used for the drawing design, the future value of the embroidery collection cannot be guaranteed. However, AI painting can be used for relatively low-end product development, as the technology does reduce costs to some extent, allowing young people interested in embroidery to purchase their own products at relatively low prices.

Therefore, the younger group (under 35 years old) has an optimistic attitude toward the introduction of AI painting into the Canton embroidery production process and can be the focus of this study, as determined by the preliminary research.

3.2 Extraction of prompts from AI drawings for Canton embroidery

The 124 Ju Lian paintings were submitted to Chat-GPT for prompts extraction around the five aspects of Theme, color, Style, Composition, and Atmosphere, but 14 failed to be identified due to insufficient resolution of the paintings; the basic response format is as follows:

Theme: two colorful birds perched on a flowering branch

Colors: various shades of green, blue, red, and yellow

Style: traditional Chinese painting

Composition: a clustered arrangement of birds and blossoms, with some overlapping

Atmosphere: lively and energetic

The descriptions of Chat-GPT are repetitive, and excluding the excessively simplistic and inaccurate descriptions, Table 2 summarizes the three dimensions other than Theme and color.Due to the fact that Chat-GPT is insufficient for summarizing the two dimensions of Theme and color, it is currently impossible to determine the precise color parameters of specific species and targets; therefore, additional summaries based on field research are required.Table 3 classifies the major themes of Canton embroidery into five categories. Due to translation and regional species, Paradisaea apoda and golden Arowana have been discovered, and AI recognition is currently insufficiently precise.Through field research in a Guangzhou embroidery craft factory, this study utilized a (Deta) digital colorimeter to extract color from a selection of Canton embroidery works and silk threads (Figure 3) in an attempt to compile a color library for Canton embroidery. Red, green, blue, and yellow were categorized as the four

primary color families in order to select appropriate colors for implementation in this study and to provide a color reference for subsequent studies, including both RGB and CMYK data.

Table 2. The Prompts given by chat-gpt.

Style	Composition	Atmosphere
traditional Chinese painting	…use of negative space and asymmetry to create a sense of balance and harmony; ...use of negative space to highlight the subject; …which are arranged in a harmonious and balanced manner; a simple composition with one … and some... with …; …and …with some overlapping; Central focus on ….	calm, tranquility, a sense of joy and happiness, a celebration of nature and the beauty of flowers, delicate, detailed, festive, vibrant, lively, elegant, soft, gentle, harmonious, peaceful dreamy, ethereal, whimsical, graceful, serene, intricate, natural, textured

Table 3. Themes for Embroidery.

Flower	Fruit	Insect	Bird	Fish
Peony, lotus, chrysanthemum, Bauhinia × blakeana Dunn,Delonix regia (Boj.) Raf., Kapok, Plumeria rubra 'Acutifolia'	Litchi chinensis Sonn	Butterfly, bee, dragonfly	Sparrow, bulbul, Chinese copper pheasant, eagle, Zebra finch, Paradisaea apoda, kingfisher, Paradise-flycatcher, chicken, peacock, mandarin duck, white duck, goose, red-crowned crane, parrot	Goldfish, koi, Golden Arowana

Red
R:205 G:108 B:114 C:20 M:68 Y:43 K:0
R:182 G:75 B:87 C:32 M:82 Y:56 K:0
R:192 G:54 B:76 C:25 M:91 Y:61 K:0
R:173 G:43 B:39 C:36 M:96 Y:96 K:2
R:180 G:56 B:51 C:33 M:91 Y:84 K:1
R:137 G:51 B:73 C:51 M:91 Y:62 K:11
R:139 G:28 B:45 C:47 M:100 Y:86 K:16
R:147 G:29 B:47 C:44 M:100 Y:85 K:12
R:127 G:26 B:41 C:49 M:100 Y:87 K:23

Yellow
R:206 G:181 B:70 C:24 M:27 Y:80 K:0
R:191 G:167 B:74 C:31 M:33 Y:79 K:0
R:188 G:182 B:144 C:31 M:26 Y:46 K:0
R:178 G:130 B:70 C:36 M:53 Y:79 K:0
R:177 G:149 B:65 C:38 M:49 Y:73 K:0
R:174 G:136 B:81 C:38 M:49 Y:73 K:0
R:179 G:160 B:97 C:36 M:36 Y:68 K:0
R:154 G:131 B:42 C:47 M:48 Y:98 K:1
R:149 G:145 B:53 C:49 M:38 Y:93 K:0

Green
R:161 G:174 B:136 C:43 M:24 Y:51 K:0
R:148 G:170 B:147 C:48 M:25 Y:44 K:0
R:113 G:132 B:101 C:63 M:43 Y:65 K:0
R:83 G:120 B:52 C:73 M:44 Y:100 K:4
R:102 G:142 B:76 C:66 M:33 Y:84 K:0
R:116 G:151 B:104 C:61 M:30 Y:67 K:0
R:78 G:99 B:64 C:74 M:54 Y:84 K:15
R:53 G:82 B:41 C:80 M:57 Y:100 K:29
R:50 G:69 B:42 C:80 M:62 Y:91 K:0

Blue
R:149 G:172 B:177 C:47 M:25 Y:27 K:0
R:62 G:98 B:126 C:81 M:60 Y:40 K:1
R:3 G:99 B:144 C:89 M:58 Y:27 K:0
R:0 G:113 B:109 C:87 M:46 Y:60 K:2
R:37 G:59 B:96 C:93 M:84 Y:46 K:12
R:5 G:57 B:79 C:96 M:79 Y:56 K:26
R:27 G:56 B:61 C:89 M:72 Y:67 K:39
R:27 G:56 B:61 C:89 M:72 Y:67 K:39
R:32 G:37 B:49 C:87 M:83 Y:67 K:49

Fig.3. A portion of the color gamut for Canton embroidery.

3.3 Combination of lotus and butterfly as an example of design output

To ensure that AI can precisely identify the subject matter of large embroidery paintings, it is necessary to submit the corresponding theme in advance. Among them, the popular subject matter of lotus and butterfly is easier to recognize, and the combination does not require specific specific birds in Canton embroidery as birds typically do, allowing AI's specialty to be performed more freely in the experiment for summarization. This study prioritizes the coupling of lotus and butterfly for practice in order to provide an example of how to apply the corresponding steps to other subjects.

In this study, the AI painting generation processes are primarily divided into four sequential steps: (1) Determine Theme, Style, and Composition, and select corresponding prompts from Tables 2and 3. (2) Determine Atmosphere, and select pertinent prompts from Table 2. (3) Specify the Canton embroidery color used. Select hue from Figure 4 (4) Painting cycle Generate four times and select the best results. Following is a detailed explanation of how artificial intelligence generates paintings.
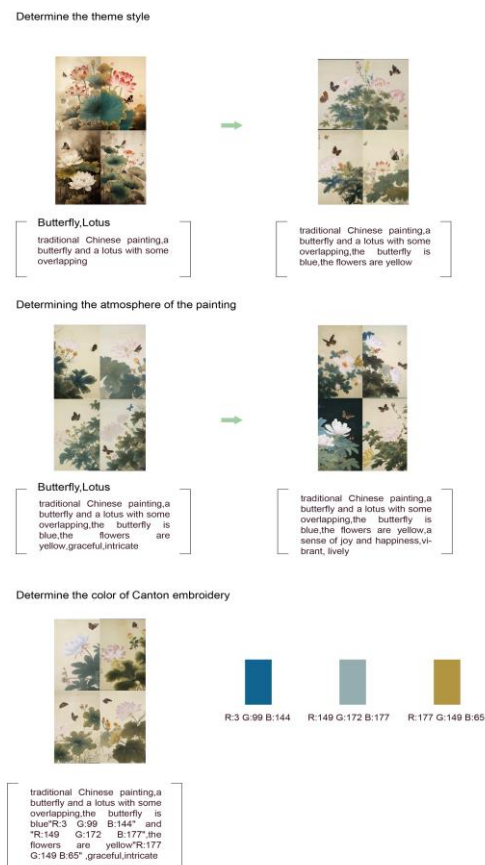

Fig.4. The first three steps generate the paintings.

Through the three stages of determining the theme's style and composition, the painting's atmosphere, and the specific Canton embroidery colours used, it has been possible to generate target sketches from five aspects: theme, composition, colour, style, and atmosphere. To demonstrate the validity of the keywords and the generated sketches, since Midjourney was able to provide 4 sketches each time, the final keywords were resubmitted 4 times, and the 1 sketch that best matched each time was chosen to produce 4 sketches as a result (Figure 5).

Fig.5. Lotus, butterfly combination final generation effect.

3.4 Assessment for target group

For a comprehensive evaluation of the design, the Customer Satisfaction Index (CSI) uses the following standard method to compute the scores for each of the five dimensions.

$$CSI = \frac{E(\eta) - Min(\eta)}{Max(\eta) - Min(\eta)} \times 100 \qquad (1)$$

Where η denotes the satisfaction of the research users, is the hidden variable, E (η), Max (η), Min (η) denote the expected, maximum and minimum values of overall customer satisfaction, respectively. This paper is a 7-level scale question, Min (η) = 0, Max (η) = 6. The overall satisfaction level is 61.05, which is an acceptable level (>61), indicating that the combination of AI drawing and wide embroidery in this study is generally acceptable to young consumers and the study results are feasible. To ensure that AI painting has practical applications, two single options were introduced to the target consumer groups in Table 4 to clarify the direction of future research and application scenarios. In all aspects, the popularity of AI painting was relatively average, and there was no apparent frequency gap, indicating that AI painting in Canton embroidery is more important for achieving an overall comprehensive effect than for determining individual preferences. In terms of product application preferences, the youth group selected products with greater practicality in life and relatively lower prices, while only 6.28 percent selected the current mainstream products of Canton embroidery (traditional fine embroidery wall paintings), indicating that the needs of the youth group differ from those of the stable consumer group of Canton embroidery at present, and overlap with the needs of the youth group from the previous study, who also desire products with greater practicality in life. They are also interested in purchasing a variety of useful embroidery products.

Table 4. List of embroidery workers.

Which part of the above paintings do you like the most?						
Theme	Color	Composition	Style	Atmosphere	Texture	AI generated

Frequency	26	27	40	34	36	38	38
Percentage	10.88%	11.3%	16.74%	14.23%	15.06%	15.9%	15.9%

Which embroidery product would you prefer to use if the above illustrations were to be used in a variety of embroidery products?

	Fine hangings	Clothes	Luggage	Accessories	notebooks, bookmarks, etc.	fans, cup covers,etc.	DIY sets
Frequency	15	29	44	35	49	36	31
Percentage	6.28%	12.13%	18.41%	14.64%	20.5%	15.06%	12.97%

3.5 Canton Embroidery Workers Assessment

Canton embroidery is characterised by embroidery techniques, which are more apparent in their application. Ms. Wu (NO.2) stated that the embroidery stitches should be matched to different parts of the painting, such as the embroidery of birds' feet and lychees, and only after the matching is completed can it be said that the work has the characteristics of embroidery from the drawing to the embroidery method and the whole.

Manager Zhang (NO.8) stated that in production practise, AI paintings are applicable to comparatively low-end products (partially decorated scarves and shawls, notebooks, postcards, fans, cloth stickers, DIY material kits) and have greater cultural dissemination significance. Due to the current shortage of Canton embroidery workers, they are only able to satisfy the initial demand for hanging paintings; if AI painting is used for high-level hanging paintings, the workload will exceed the load, and it will be too labor-intensive.

The introduction of AI painting can attract many young people, which is beneficial for the promotion of Canton embroidery's popularity and has a new way to attract the public on the new media platform, and it has the unique property of being able to generate corresponding drawings according to one's own needs, which is very interesting and corresponds well to the product of DIY material kit, as well as providing new inspiration for Canton embroidery's products in printing.

4. Results

This article extracts prompts based on five fundamental elements of paintings: Theme, colour, Style, Composition, and Atmosphere, and summarises the artistic characteristics of Canton embroidery through Chat-GPT and field research.

The CSI results of AI drawings indicate that Innovativeness, Artistry, and Regional feature preference are acceptable to the youth group, but there is still much room for improvement. The design process, the library of drawing materials, and the number of prompts must be enhanced in order to increase customer satisfaction. We must increase customer satisfaction by enhancing the design procedure, enlarging the drawing materials library, and increasing the number of prompts.Consumer willingness is low (≤ 61), indicating that there is a lack in the dissemination of embroidery culture. Although AI drawings have reached an acceptable level for young people in terms of innovation, aesthetics, and cultural characteristics, the lack of understanding of the embroidery process still has a negative impact on consumer willingness.

Canton embroidery practitioners, on the other hand, generally gave positive suggestions for AI to complete the drawing design, believing that the application is feasible and conducive to

expanding business and passing on culture and skills, thereby sparking new ideas for industry development. However, AI drawings are only suitable for relatively low-priced craft products and cultural communication, and the workload of AI drawings for advanced hanging would exceed the load and woe of the embroidery practitioners.

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