Research Article

Utilization of MultiLevel Drawing Technology for Computer-Based Embroidery Employing Computerized Digital Technology

Yinglu Wu

Department of Art and Design, Guangzhou Institute of Technology, Guangzhou 510000, Guangdong, China

Correspondence should be addressed to Yinglu Wu; wjn@gzvtc.edu.cn

Received 1 March 2022; Revised 6 April 2022; Accepted 25 April 2022; Published 19 May 2022

Academic Editor: Naeem Jan

Copyright © 2022 Yinglu Wu. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

In this study, the theoretical foundation of the manually operated crewel embroidery technology was suggested to enhance the artistic features of computerized embroidery. By doing so, the advantages such as mass production, more realistic pictorial patterns, and increasing artistic demand by users can be realized. Hence, the embroideries characterized by the computerized mechanical and crewel methods could be compared. Therefore, interesting results were obtained. The software called WILCOM and a single head computerized embroidery machine with 12 needles having multifunctionality called TUMX-C1201 were utilized to produce proofing size designs of embroidery frames with a selection of a base needle, color, and style of the pattern for the layered combination. Then, both computerized mechanical embroidery and crewel embroidery generate binding assays. The outcomes suggest that proofing samples with the gray value of 15 groups utilizing stitch spacing varying between 0.2 mm and 3 mm designate a gradual inclination in the upward direction when different bases of needles, namely, 10 mm, 20 mm, and 30 mm are under consideration. In other words, an obvious trend and a stable state were simply observed when they change between 0.2 mm and 1.8 mm and between 1.8 mm and 3 mm, respectively. For example, when a 50 × 50 mm area was taken as an illustrative example, 102, 24, and 5 base needles were needed, respectively. As a result, certain characteristics were observed in the visual style when computerized mechanical crewel embroidery was employed, which is, for example, a certain degree of looseness contained in the stitching of the petal pattern that created vividness and enhanced hierarchical sensation. Besides, the petals of a sunflower in three dimensions were seen concurrently. Thus, the computerized digital technology enables computer-based embroidery to draw patterns in multilevel artistic processes and was concluded. Combining manual and computer-based embroidery could not only succeed in mass production but also enhance the aesthetic aspects of embroidery works.

1. Introduction

The development of society leads to a continuous improvement of living standards for people and gradually feeds a flourishing embroidery market. Thus, the market demand for embroidery products has been greatly increased. However, traditional manual embroidery has an issue of low production volume and high price due to its time-taking production process, which leads to an imbalance of supply and demand in the traditional manual embroidery market [1]. Hence, computer-based embroidery with its advantages of mass production and relatively low cost has become a very popular means in the market.

Unlike the techniques of traditional embroidery, computer-based embroidery technology can use the combined facilities of both hardware and software to conduct mechanized design of some stitches realized in traditional manual embroidery works. Besides, a good impression of traditional embroidery needling accompanying mass production leads to low cost and high completion and impression impact on users that would increase artistic features of those works [2].

In the current mechanized production, although the processing speed of computerized mechanical embroidery is fast and the necessary investment is small, there are still many shortcomings that need to be dealt with [3]. The fundamental aspects of machine-based embroideries were
presented in [4] and the working principles of the rich peace embroidery machine were presented in [5]. Several different approaches have been employed to better generate embroidery works. Ren et al. [6] proposed a novel method that utilizes fine-grained printing on textile using registered images for embroidery works. Nejad et al. [7] suggested a novel method that utilizes a laser for the edge trimming of fabric embroidery. Briedis et al. [8] proposed a method that embedded electronic components in the embroidery work. Post et al. [9] conducted research that investigates numerically controlled embroidery machines for the conductive thread. Jimoh et al. [10] investigated different handmade embroideries in Nigeria to generate a database to protect them for generations. Wang [11] examined the traditional Chinese embroidery works to cover all aspects of it that include patterns, colors, materials, techniques, and other traditional pillars of embroideries to apply to computerized ones. Lin et al. [12] proposed a method based on an intelligent system to produce customized embroideries. Wyszecki et al. [13] presented the concepts, methods, and quantitative data with the formulations used.

On the contrary, mechanical embroidery cannot completely replace manual embroidery, and many complicated traditional manual embroidery techniques cannot be realized by computerized mechanical embroidery. Besides, the computer still cannot succeed in expected goals with specified details. Due to the limitation of both software and hardware issues and other factors as well, the final effect of computer-based equipment will not be satisfactory in the design of embroidery patterns. Many new designs cannot be realized and mass-produced. The form of computerized embroidery products in the embroidery market has been very similar, namely, diversification is still an issue [14]. The emergence of crewel embroidery makes the three-dimensional sense of embroidery image more realistic, and the level of color is also very vivid. Even if the stitching is very dense, it does not make people feel overwhelmed. When compared with regular computerized mechanical embroidery, the stitching effect is more relaxed and lively.

The process characteristics and ravishing artistic effect of crewel embroidery need to be combined with computerized digital technology. Therefore, an attempt will be conducted to develop a crewel technology that composes of both crewel embroidery and computerized mechanical embroidery, thus, presenting a multilevel artistic drawing process and providing a practical basis for the development of embroidery technology. The main motivation of this research is to investigate two parameters that make a significant contribution to embroidery works, which is called the position of the take-off needle and the distance between stitches since they have an impact on vividness and enhancement of the hierarchical sensation. For example, when the diameter of the base needle is large, and the distance between the stitches gradually increases to a certain range, and the stitch density does not change.

The rest of the organization of the study is as follows. Section 2 presents the preliminary. Section 3 is related to our research that introduces the theoretical foundation of the manually operated crewel embroidery technology into computerized mechanical embroidery and compares these two methods. Section 4 is allocated to results and discussion. Section 5 concludes the research.

2. Preliminary

In this section, we briefly provide details of manual crewel embroidery technology, computerized mechanical embroidery, and the comparison of the computerized mechanical embroidery with the crewel embroidery concerning methods, requirements, colors, and the number of layers.

2.1. Manual Crewel Embroidery Technology. Embroidery refers to the technology of embroidering various patterns on the fabric with needles and threads. Based on the relevant texture and specified patterns, the embroidery needle repeatedly punctures the silk threads with different colors and textures on the embroidered cloth and finally creates designed patterns on the cloth [15]. Crewel embroidery, with its novel embroidery technology and unique artistic expression, has a unique special charm among the embroidery techniques. It is even praised as “China’s fifth most famous embroidery.” Figure 1 shows the flower and portrait patterns utilizing the crewel embroidery method.

The origin of crewel embroidery is called Suzhou embroidery, which is different from traditional manual embroidery in that it is characterized by “close stitching and parallel thread.” Both the Chinese and Western art features are combined in this type of embroidery method. For example, the point killing, perspective, and brushwork mechanism of foreign oil painting are combined with traditional Chinese embroidery technology. Lines with different lengths and complicated arrangements are used for texture description, and the color of the pattern, as well as the changes in both light and dark areas, are shown utilizing the layered permeating method [16], which results in a unique needlework process. This embroidery technology is more suitable for the characteristics of oil painting and photography.

![Figure 1: A flower pattern utilizing crewel needle embroidery.](image-url)
The characteristics of the finished products created by crewel embroidery consist of various colors, lively styles, disorderly but not complicated stitches, and strong artistic forms. The patterns presented are mostly very exquisite and delicate, which have been widely recognized around the world and assessed as rare art treasures. Moreover, as a representative of Chinese traditional art, it is presented to important foreign leaders several times in the form of an official present. Jiangsu Province has incorporated the crewel embroidery technology into the first batch of intangible cultural heritage, and the Chinese government has also included the crewel embroidery technology into the application plan of the world intangible cultural heritage as a mutual initiative [17].

2.2. The Computerized Mechanical Embroidery. Computerized mechanical embroidery refers to utilizing professional digital technology based on running computer programming, setting the order of needlework, and designing the patterns needed for embroidery to realize the production of embroidery products. Figure 2 depicts a conventional computerized mechanical embroidery.

The core reason for the emergence of computerized mechanical embroidery is that manual embroidery cannot meet the actual market situation that is coupled with the rapid development of science and technology. The main steps to realizing computerized mechanical embroidery technology can be summarized as follows.

First, embroidery patterns are created by special designers.

Second, the pattern maker uses professional embroidery software to print the plate and then imports it into the computerized mechanical embroidery machine to finish the trial weaving and trial edition.

Third, professional embroidery workers repeatedly modify and optimize the color and needling method of the trial embroidery samples to form the style of the final version, and then, the embroidery machine will carry out the large-scale production at the final stage.

2.3. The Comparison of the Computerized Mechanical Embroidery with the Crewel Embroidery. When compared with traditional manual embroidery, the advantage of computerized mechanical embroidery can be summarized as follows: a mass production capability that cannot be the case in traditional manual embroidery. Computerized mechanical embroidery achieves a larger number of patterns generated. The improved computerized mechanical embroidery can even imitate more complex techniques such as cording embroidery [3].

The comparison and summaries of the features of both computerized mechanical and crewel embroideries are presented in Table 1.

3. Research

In this section, we present each step of the research based on the implemented software and the machine that produces the samples used in the comparison study.

3.1. Binding Assay Based on the Computerized Mechanical and Crewel Embroideries

(1) Software facilities: the WILCOM embroidery software (WILCOM company, Australia) is the producer of both embroidery drawings and pattern-making software that can be utilized to edit pattern files that belong to the source of computerized mechanical embroidery [18]. At present, the WILCOM software has gradually improved its technology and has included a strong and creative capability to cover extensive embroidery, which enables embroidery designers to utilize more powerful functions for embroidery design. Besides, the WILCOM embroidery software can move the vector diagram and embroidery unit and can also conduct a series of operations such as sample design, style improvement, and detection in one-stop mode. Hence, it can help meet all kinds of design requirements by designers, debugging the performance of embroidery, and achieving the final embroidery product design with the highest quality. Therefore, the WILCOM embroidery software is utilized to deal with the digital processing of design patterns in this manuscript.

Specific needles within software are used as base needles. The parameters such as the position of the take-off needle and the distance between stitches were experimented with concerning the stitch track of the computerized mechanical crewel embroidery. After analyzing the pattern stitch, the WILCOM software is run to simulate the stitch state of the embroidery. The operation process is summarized as follows.

First, files are created in software to edit the pattern. Second, the designed pattern is imported into the file; then, the selection of the matching stitch is conducted employing the pattern-making tool, and the aforementioned parameters are imported to implement the stitch design of the pattern. Based on the
painting characteristics of the impressionistic pointillism school, the three-dimensional sense and color level of the pattern is designed by the utilization of the base needle.

Third, the file is saved into the computer with the EMB format to implement the modification of stitch parameters in the software later, and it is saved to the embroidery disk in the DST format to facilitate the computer embroidery machine system to select data and complete the machine embroidery according to the pattern-making design process. When pattern-making of embroidery is carried out, the measuring ruler on the WILCOM software should be used to gauge, and the designed embroidery pattern should be less than the maximum embroidery range of the embroidery frame. The maximum size of embroidery frame proofing employed in this experiment is 35 cm wide and 30 cm long.

(2) Computerized embroidery machine (hardware facilities): a machine called TUMX-C1201 has 12 needles with multifunctionality of a single-head computer embroidery (TAJIMA embroidery machinery (China) Co., Ltd.). The maximum embroidery area of the embroidery machine is $40 \times 35$ cm$^2$. The two areas of the embroidery and moving frame play their respective functions, and they will coordinate the work at the same time. Afterward, the two areas deal with the embroidery process together, which belongs to the core part of the computer embroidery machine to finish the embroidery. The working phase of the computerized embroidery machine will utilize the electronic controller to conduct the data reading and decoding analysis so that all motors can cooperate. The mechanical movement direction of the computer embroidery machine is divided into $X$-axis and $Y$-axis, respectively. With the continuous movement of the embroidery frame, the embroidery works are finished.

(3) Design of layered combination: first, the color extraction and layering operation are conducted for the digital pattern of the color; then, the pattern is divided into several single-layer patterns.

Second, gray level processing is carried out for all single-layer patterns, which means that color images are transformed into black-and-white images by image processing software to obtain grayscale images of the single-layer patterns. The matching relationship between the single-layer gray pattern and each stitch parameter of computerized mechanical crewel embroidery is set concurrently. Thus, the corresponding stitch arrangement is set to obtain the single-layer stitch pattern. Converting color to grayscale is done by taking the linear combination of $R$, $G$, and $B$ channels, which is the widely implemented and effective approach. The $R$, $G$, and $B$ channels are utilized as weighted linear functions to transform color into a grayscale representation of the given image [6]. The mathematical representation for this process is expressed in

$$I_g = \beta^T I_c,$$  \hspace{1cm} (1)

where $\beta$ is a projection vector, $I_c$ is a color image, and $I_g$ is a grayscale image.

Third, all the single-layer stitch patterns are superimposed together to form a composite stitch layout pattern in the embroidery pattern-making software.

Fourth, the colorful embroidery thread is allocated in a proper form, and machine embroidery is implemented to form computerized mechanical crewel embroidery works.

4. Results and Discussion

In this section, we present the results of the research with some figures that depict numerical values and a picture of the produced product that provides vividness and hierarchical sensation.

<table>
<thead>
<tr>
<th>Table 1: The comparison of the characteristics of the computerized mechanical embroidery with crewel embroidery.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embroidery technology</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Crewel embroidery</td>
</tr>
<tr>
<td>Computerized mechanical embroidery</td>
</tr>
</tbody>
</table>

Figure 3: The gray value of 15 groups of stitch proofing objects.
4.1. Image Gray Value under the Different Stitches. The 10 mm, 20 mm, and 30 mm base needles are selected to gauge the gray value of 15 groups of samples. Figure 3 depicts the results.

When a base needle of 10 mm is picked, a trend with a gradual upward direction can be seen concerning the gray value of 15 groups for the proofing objects. The stitch spacing changes between 0.2 mm and 3 mm are presented in Figure 3. Hence, an evident trend and a simple stable state can also be observed between 0.2 mm and 1.8 mm and between 1.8 mm and 3 mm, respectively. An area of 50×50 mm is arranged based on 102 base needles. On the contrary, when 20 mm and 30 mm base needles are utilized, respectively, the gray value of 15 groups for the proofing objects having stitching spacing that changes between 0.2 mm and 3 mm and follows the same tendency in the upward direction with 24 and 5 base needles, respectively.

Relevant studies show that the larger the gray value of the stitched image is, the lighter the color of the image would be; that is, the lightness is also gradually enhanced [19]. If the light and shade of the image do not change significantly, then the ends of some thread will be left during the routing of the pattern stitch, or the diameter of the ends of the thread may be different. In other words, when the diameter of the base needle is large and the distance between the stitches gradually increases to a certain range, the stitch density does not change. This situation implies that if the gray values are similar in the process of the parameter selection, the operation of the partition selection should be carried out in an interval with similar discrimination.

4.2. The Overlay Effect of the Layered Pattern. Embroidery work utilizing intersecting stitches to make the colored image more realistic on a piece of fabric is a way of reproducing patterns in three-dimensional impressions. By doing so, multilayering and overlapping realized purposely produce true-color subjects. In other words, stitches are superimposed on each layer to generate true-color subjects. Thus, the overlay effect can be seen on fabrics more realistically.

According to the results presented in Section 4.1, the sunflower pattern is taken as an illustrative example. Three single-layer stitches of bedding, coarse embroidery, and fine embroidery are superimposed in turn to obtain the actual image effect of the computerized mechanical crewel embroidery with the computer proofing and the common computerized mechanical embroidery as presented in Figure 4.

Certain features can be observed concerning the visual style of the computerized mechanical crewel embroidery in Figure 4. The method, called computerized mechanical crewel embroidery, creates the stitching of the petal pattern that includes looseness to a certain degree, which results in vividness and enhances a hierarchical sensation. The petals of the sunflower with three dimensions can be seen obviously, so it designates a certain degree of artistic conception and abstract effect. Besides, it reveals that the stitch arrangement of the computerized mechanical crewel embroidery method is hierarchical, and the color of the base cloth will change based on altering the spacing arrangement of the base needle, that is to say, the artistic effect of the whole pattern is also closely related to the color of the base cloth, which can fuse the base color of the cloth with the embroidery thread color to create an embroidery pattern with a stronger visual sense.

5. Conclusion

When the fundamental foundations of the crewel and computerized-based embroideries were under consideration, both have own advantages and disadvantages. While traditional manual embroidery is known for low production and high price issues, mechanical embroidery cannot completely replace manual embroidery and many complicated traditional manual embroidery techniques. Thus, a combination targeting to utilize both of the advantages is proposed to enhance the artistic features of computerized embroidery. Therefore, a comparison study was conducted employing the fusion of two attributes.

The embroidery software called the WILCOM and a computerized embroidery machine called TUMX-C1201, a single head computerized embroidery machine with 12 needles having multifunctionality, were employed to finalize the size design of the proofing of the embroidery frame, choosing base needle, color, and style of the pattern of the layered combination.

The selection of a base needle with 10 mm causes a gradual trend with an upward direction concerning the gray value of the proofing objects. Thus, the stitch spacing alters between 0.2 mm and 3 mm. Moreover, a stable state is observed between 0.2 mm and 1.8 mm and between 1.8 mm and 3 mm. For example, an area of 50×50 mm is utilized as...
an illustrative example and utilizes 102 base needles with 
10 mm. On the contrary, when 20 mm and 30 mm base 
needles are employed, respectively, the gray value of the 
proofing objects having stitching spacing that changes be-
 tween 0.2 mm through 3 mm follows the same tendency in 
the upward direction with 24 and 5 base needles.

Therefore, the larger the gray value of the stitched image 
is, the lighter the color of the image would be, that is, the 
lightness is also gradually enhanced. In other words, when 
the diameter of the base needle is large, and the distance 
between the stitches gradually increases to a certain range; 
the stitch density does not change. This situation implies that 
if the gray values are similar in the process of parameter 
selection, the operation to select the partition should be 
carried out in an interval with similar discrimination.

In conclusion, when the base needle of the embroidery 
work is smaller than that of the base point needle, the greater 
discrimination of the gray value is more suitable for mul-
tilevel artistic drawings. Moreover, when the gray value 
becomes dense, the segment selection in the range should be 
carried out. By continuously adjusting the parameters of 
the base needle and superimposing the three-layer stitch, the 
computerized mechanical crewel embroidery method makes 
the sunflower petal pattern have a higher sense of level, 
which not only looks lively but also has an obvious three-
dimensional effect.

Data Availability

The data will be provided from the corresponding author 
upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

This work was supported by Double tutor Studio of Cultural 
and Creative, the first batch of Double Tutor Studio Project 
of Guangzhou Higher Vocational Education in Guangzhou 
Universities, 2019 (No. 2020SS007), and Zhanpeng Tan & 
Minjian Huang Master Studio of Guangzhou Embroidery, 
the first batch of Accreditation projects of Guangdong 
Higher Vocational Education Teaching Quality and 
Teaching Reform, 2018 (No. 22).

References

evaluation of the uncertainty of the research method on the 
geometrical parameters of the embroidery elements,” Journal 
of the Textile Institute, vol. 110, no. 8, pp. 1–8, 2018.
of an IMU Integrated clothes for postural monitoring using 
conductive yarn and Interconnecting technology,” Sensors, 
luminance efficiency of the machine embroidery method 
applied to flexible plastic optical fiber for the realization of the 
textile display,” Textile Research Journal, vol. 88, no. 13, Article 
ID 004051751770319, 2017.
mechanical principle of embroidery machine,” Mechanical 
rich peace embroidery machine,” Journal of Wuhan, Textiles 
printing system based on image registration,” Computers in 
edge trimming of fabric embroidery by laser,” Mecha-
smart garment prototype with enuresis alarm using an em-
broidery-machine-based technique for the integration of 
electronic components,” Procedia Computer Science, vol. 104, 
[9] E. R. Prost, M. Orth, P. R. Russo, and N. E. Gershenfeld, 
“Design and fabrication of textile-based computing,” IBM 
“Handmade embroidery pattern recognition: a new validated 
database,” Malaysian Journal of Computing, vol. 5, no. 1, 
modern design,” vol. 368, pp. 232–234, in Proceedings of the 
3rd International Conference on Art Studies: Science, Experi-
ence, Education (ICASSEE-2019), vol. 368, Atlantis Press, 
Moscow, Russia, October 2019.
based on the intelligent system,” in Proceedings of the 2nd 
International Conference on Electrical, Control and Auto-
mation Engineering (ECAE-2017), vol. 140, pp. 300–303, Xiamen, 
China, December 2017.
Methods, Quantitative Data and Formulae, Wiley-Inter-
[14] K. Yang and Z. Sun, “Paint with stitches: a style definition and 
image-based rendering method for random-needle embroi-
dery,” Multimedia Tools and Applications, vol. 77, no. 10, 
Article ID 12259, 2018.
designed electro-textile wearable tag antenna for WBAN 
[16] Z.-N. Xue, Y.-J. Yu, and X.-G. Tian, “Transient responses of 
multi-layered structures with interfacial conditions in the 
generalized thermoelastic diffusion theory,” International 
[17] Q. Bao, “The application of big data technology in the research of 
ancient Chinese silk road,” Journal of Physics: Conference 
[18] Y.-G. Wang, R. H. Miyakawa, W. Chao, and P. P. Naulleau, 
“Efficient Fresnel zoneplate pattern data preparation for high-
resolution nanofabrication,” Optics Communications, vol. 402, 
assessment for color-to-gray image conversion,” IEEE 
Transactions on Image Processing, vol. 24, no. 12, pp. 4673– 
4685, 2015.