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A study on the integration mechanism between generative algorithms and paper-cutting art

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Abstract. This paper explores the integration mechanism between generative algorithms and traditional Chinese paper-cutting art. Against the backdrop of rapid advancements in digital technology, generative algorithms have become an important tool in artistic creation, revitalizing paper-cutting art through the modernization of traditional artistic forms. Beginning with the shift in visual culture in the digital age, this paper analyzes how generative algorithms promote new modes of artistic expression. It then discusses the modern transformation of paper-cutting art, particularly focusing on the application and transformation of digital technologies and generative algorithms in paper-cutting design. Finally, using the design of theatrical characters in paper-cutting style as a case study, it compares the performance of different AIGC tools in generating traditional artistic symbols and examines the potential of generative algorithms in art education through curriculum practice. The study shows that generative algorithms not only improve the efficiency and diversity of traditional art creation but also provide ample space for its inheritance and innovation.

Keywords: generative algorithms, paper-cutting art, integration mechanism, educational innovation

1. Introduction

The discussion of generative algorithms in China can be traced back to 1981, when Ding Youyu first proposed the concept in his article, identifying them as a type of inference algorithm based on context-free grammars [1]. Given the technological level and hardware conditions at the time, there were few viable directions for practical application. However, in the contemporary era marked by rapid advancements in digital and artificial intelligence technologies, generative algorithms—technologies capable of automatically generating content through data-driven learning—have emerged as powerful tools in artistic creation. From images to music, and from literature to animation, generative algorithms have significantly enhanced both the diversity and efficiency of artistic production. Although generative art has a relatively short history, it possesses immense potential for future development [2]. In stark contrast, traditional handmade arts such as Chinese paper-cutting, despite their deep cultural heritage and broad public recognition, are facing multiple challenges: limited modes of creation, restricted channels of transmission, and a disconnection from modern aesthetic sensibilities. How to preserve the traditional aesthetics of paper-cutting while endowing it with new expressive possibilities through modern technology has become a pressing issue for both artists and researchers. In today's era of visual cultural transformation, the application of generative algorithms offers a promising

solution to this problem. Building on computer-assisted generation of paper-cut designs [3], the introduction of intelligent generative mechanisms enables paper-cutting art to be presented on digital platforms in entirely new forms. This not only revitalizes the inheritance of traditional art but also equips creators with breakthrough tools and methods, thereby opening up new avenues for the innovative transmission of traditional culture.

2. The shift in visual culture in the digital age and the influence of generative algorithms

With the rapid development of information technology, the digital age has quietly transformed all aspects of global culture and society. In the realm of visual culture in particular, images have become essential cultural carriers and central elements in social communication. "The entire society's shift toward visual culture signifies a series of cultural transformations", leading to phenomena such as the rise of mass culture, the integration of "virtual reality" into daily life, and the emergence of an era dominated by sensory and image consumption [4]. The boundaries between traditional methods of image creation and dissemination have begun to blur. From early static photography to today's dynamic imagery, virtual reality, and AI-generated visuals, technological revolutions have not only expanded the forms and spaces of visual expression but have also redefined the meaning and function of images. These developments have prompted scholars to pay increasing attention to the social, cultural, and philosophical significance of imagery in the digital age.

2.1. The transformation of imagery in the digital age

The development of digital technology has significantly lowered the threshold for image production, resulting in transformative changes in how images are created, disseminated, and appreciated. Following the widespread adoption of photography—particularly in the digital era—the creation of images has ceased to be the exclusive domain of professional artists and has instead expanded to include the general public. The use of digital design tools has made image production more accessible and efficient, enabling anyone to become a producer of visual content. With the aid of network technologies, digital exhibitions by major museums, institutions, and even individuals through social media have made it possible to display digitalized collections online. Individuals can now quickly disseminate their work via online platforms, offering audiences under the umbrella of internet connectivity a virtual experience of artistic appreciation. This has allowed art to transcend the constraints of geography and time. Moreover, advances in storage and display technologies have made the digital archiving of artworks an emerging trend. Not only does this allow classic works of art to be preserved permanently, but it also endows them with new functions in cultural dissemination. For instance, platforms such as the Google Art Project use high-resolution scanning and online browsing technologies to enable users to explore global artistic treasures anytime and anywhere, forming a globally shared visual culture.

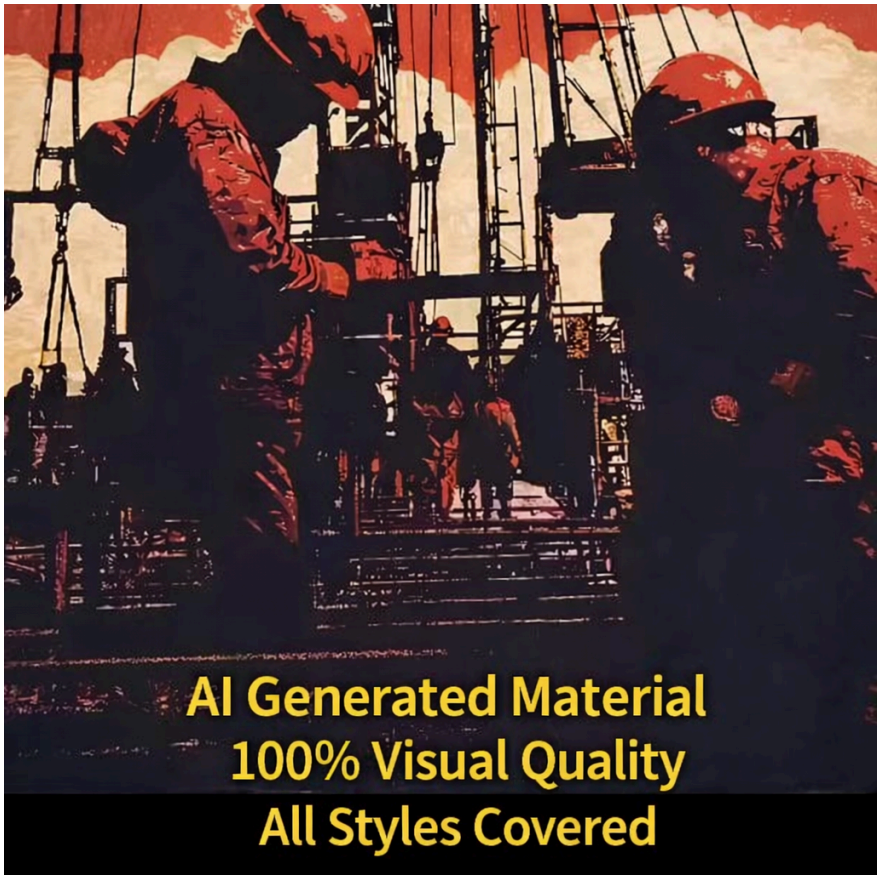

Figure 1. Source: Douyin platform, ID: "*Oil Painting, Chinese Painting, and National Exhibition Materials*"

Moreover, thanks to social media platforms, short video applications, and various cloud storage tools, platforms with strong social attributes—such as Bilibili and Douyin—have enabled images to be shared and remixed instantly and widely. In this process, visual culture has transcended the limitations of static media and is gradually taking on dynamic and interactive characteristics.

2.2. Generative algorithms and "digital realism"

Generative algorithms—particularly those based on Generative Adversarial Networks (GANs)—have become a significant force driving the transformation of image creation. "The core idea of GANs is derived from the concept of Nash equilibrium in game theory. It sets up two competing agents: a generator and a discriminator" [5]. Through the competition between these two components—one generating images and the other evaluating their authenticity—the quality and realism of generated images have been greatly enhanced. This technological breakthrough has not only been widely applied in the entertainment and commercial sectors but has also profoundly influenced the sourcing of materials in artistic creation.

In terms of artistic materials, there has been a transition from natural sketching and photographic realism to the current use of generated images. As a result, generative images are no longer merely the product of the artist's manual effort but rather the outcome of complex interactions between data and algorithms. By combining algorithms with curated datasets, artists can create highly original and expressive source materials. Prominent generative AI platforms such as DALL·E, Midjourney, and Stable Diffusion are now capable of producing stylized images of various kinds in response to textual prompts. As shown in Figure 1, some researchers have begun to train models specifically on datasets related to major national exhibitions—such as

the National Fine Arts Exhibition of China—thereby generating vast quantities of "digital realism" that diverge from representations of the natural world. Admittedly, this kind of "digital assistance" remains controversial to a certain extent. Nevertheless, much like the widespread use of photography in the 19th century, this new mode of creation significantly enhances the efficiency and diversity of artistic production, and propels visual art toward more abstract and symbolic directions.

2.3. The impact of generative algorithms on artistic creation

In contemporary artistic creation, the introduction of generative algorithms has brought artists a wider range of creative possibilities. Especially within traditional artistic forms such as oil painting and watercolor, the application of generative algorithms has innovated and expanded modes of expression. This transformation presents both significant challenges and opportunities for traditional art forms. On one hand, generative algorithms provide greater creative freedom and technical support, allowing complex designs to be completed in a short amount of time and thereby improving creative efficiency. On the other hand, generative algorithms challenge the "handcrafted" nature of traditional artistic creation, as algorithm-generated works often lack the emotional expression and personalized characteristics that emerge through the artist's manual process. As a result, such works may risk losing their original cultural depth and emotional resonance. A compelling example of the impact of generative algorithms on artistic creation is *Machine Hallucinations—New York Dreams* by Refik Anadol. In this work, Anadol used AI algorithms to transform over 100 million photographs of New York City into millions of data points, which were then reorganized based on architectural style, timeline, and thematic elements. These data not only preserve the visual record of the real world but also, through algorithmic randomness, generate a visual language that transcends direct experience. The work explores the narrative relationships embedded in the city's history, culture, and future development from multiple dimensions. This form of "data-driven art" demonstrates how generative algorithms can construct complex narrative landscapes through multidimensional connections, allowing viewers to experience the past, present, and future of a city—thus revealing the potential of generative algorithms to break the boundaries of traditional artistic media. More importantly, Anadol's creative model "visualizes the dreams of machines, creating ethereal landscapes that blur the boundary between the digital and the physical. As such, AI Data Painting not only represents a new technology, but also offers a philosophical reflection on the evolving relationship between human creativity and machine intelligence" [6], inspiring audiences to contemplate urban history and culture.

Therefore, in the digital age, the application of generative algorithms not only propels the modernization of artistic creation but also provides new approaches for balancing technological innovation with cultural heritage. In the future, artists will need to preserve the core values of traditional art forms while actively exploring the innovative applications of generative algorithms, thereby producing works that are both contemporary in form and rich in cultural depth.

3. The introduction of generative algorithms and the modernization of paper-cutting art

3.1. Contemporary interpretations of paper-cutting art

With the development of modern technology, the methods of creating and disseminating paper-cutting art have undergone profound changes. Traditionally, paper-cutting relied heavily on the artist's manual skill and the tactile perception of paper materials. In the digital era, however, the tools and techniques used in paper-cutting

creation have gradually shifted toward digital technologies. The intervention of digital tools has allowed paper-cutting to transcend its conventional physical medium, expanding the boundaries of its creative possibilities. Artists are no longer limited to working solely with physical paper; instead, they can use digital design tools to create more intricate and refined paper-cut patterns, which can then be realized through technologies such as laser cutting. The application of computer-aided design software, digital cutting machines, and laser engraving has not only enhanced the precision and complexity of paper-cutting works but also significantly increased the efficiency and scalability of artistic production, enabling traditional paper-cutting to "better integrate into the fast-paced, mass-production era of today" [7].

Artist Julia Ibbini, for example, employs digital tools and laser cutting technology to integrate computer-aided design into her creative process. She not only draws patterns with precision but also adjusts their size, shape, and layering, thereby merging paper-cutting art with modern technology to produce works with a contemporary aesthetic. These creations retain the essence of traditional paper-cutting while incorporating modern design elements, revitalizing the art form in a globalized context. In addition, digital technology has also transformed how paper-cutting art is disseminated.

Generative algorithms have already become a vital tool in contemporary artistic practice. Their unique mode of image generation breaks through the limitations of traditional creation and offers entirely new spaces for the modernization of paper-cutting art. The impact of generative algorithms on paper-cutting extends beyond mere updates to creative tools; more importantly, they catalyze a transformation in artistic thinking. Artists are no longer solely reliant on physical tools but instead harness intelligent technologies to generate and modify images through algorithms. The introduction of digital technology has prompted artists to explore how traditional paper-cutting language can be integrated with modern technologies, making paper-cutting not only a visual form of expression but also a product of the interplay between technology and culture. In this process, artistic thinking is no longer confined to conventional patterns and forms; rather, it is liberated into a broader digital space that enables richer and more diverse forms of creation.

The integration of generative algorithms has transformed the creative logic of paper-cutting art. Artists are no longer merely "craftspeople" but have become "designers" and "programmers". In this new mode of creation, artists must master not only the traditional techniques of paper-cutting but also the operational principles of digital technologies and algorithms. They must learn to fine-tune, reorganize, and optimize patterns in virtual spaces. This new approach to creation makes paper-cutting art more flexible and variable and offers artists greater room for experimentation and innovation.

3.2. The integration of AIGC technology and traditional paper-cutting art

With the continuous advancement of AI-Generated Content (AIGC) technologies, their application in the design of theatrical characters within paper-cutting art—particularly in the depiction of opera figures—has begun to yield notable results. Paper-cutting art, especially in the design of Peking Opera facial masks, uses exaggerated facial features and intricate patterns to convey a character's inner personality, emotional traits, and social identity. Traditionally, paper-cutting creation relied on scissors, blades, and paper as its primary materials. However, AIGC technologies now offer artists entirely new creative tools, greatly enhancing both the efficiency and diversity of artistic production.

As AI technologies continue to evolve, AI-generated paper-cutting works are becoming increasingly prevalent. In the realm of AI-generated imagery, platforms such as DALL·E (Figure 2), Doubao (Figure 3), and Zhipu Qingyan (Figure 4) represent three prominent generative algorithm systems. To evaluate the performance of these platforms in generating imagery in the style of traditional Chinese paper-cutting, this study uses a standardized prompt—"Generate an image of Sun Wukong in traditional Chinese paper-cutting

style"—as the basis for experimental design, and conducts a comparative analysis against *The Great Sage Equal to Heaven*, a representative work by master paper-cutting artist Ren Yude from Yu County.

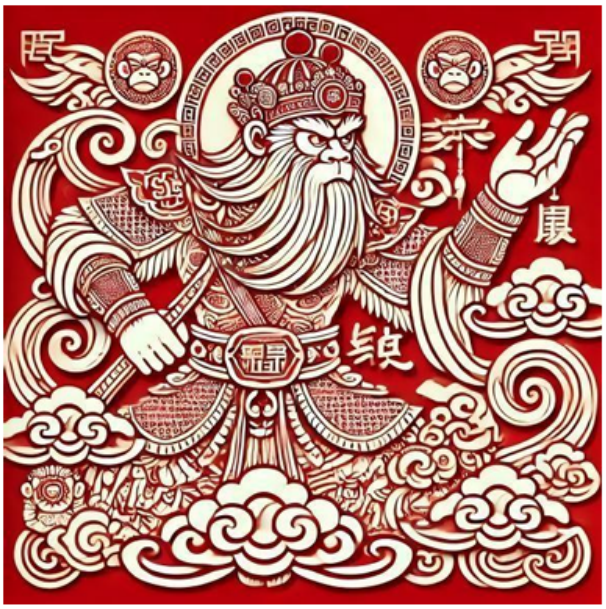

Figure 2. Image generated by DALL·E (top left)

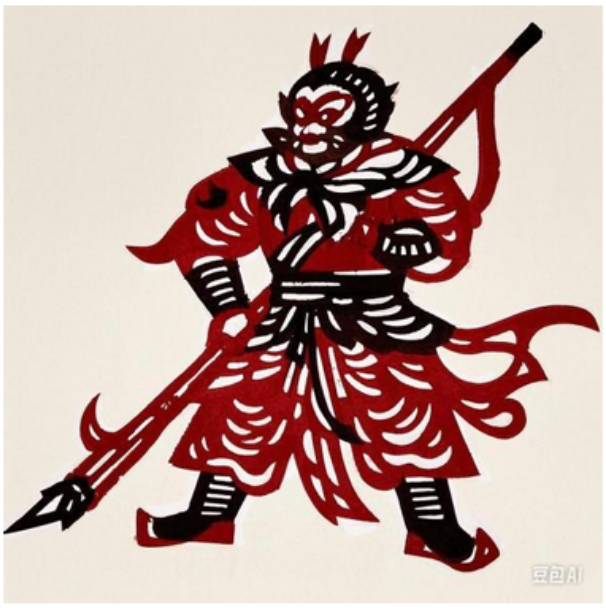

Figure 3. Image generated by Doubao AI (top right)

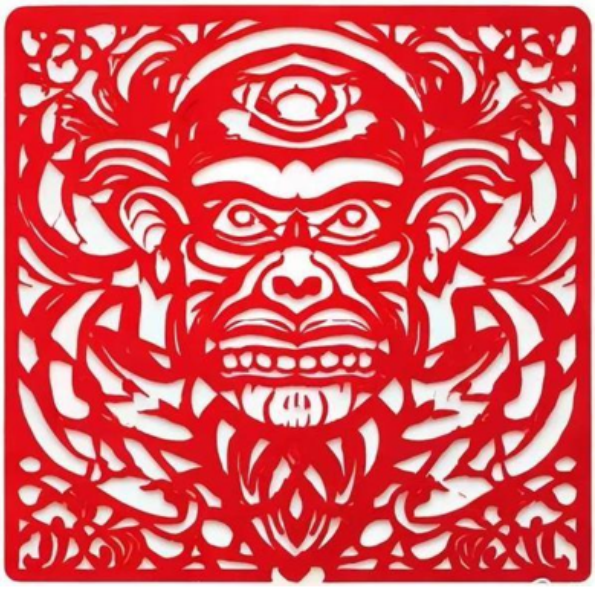

Figure 4. Image generated by Zhipu Qingyan (bottom left)

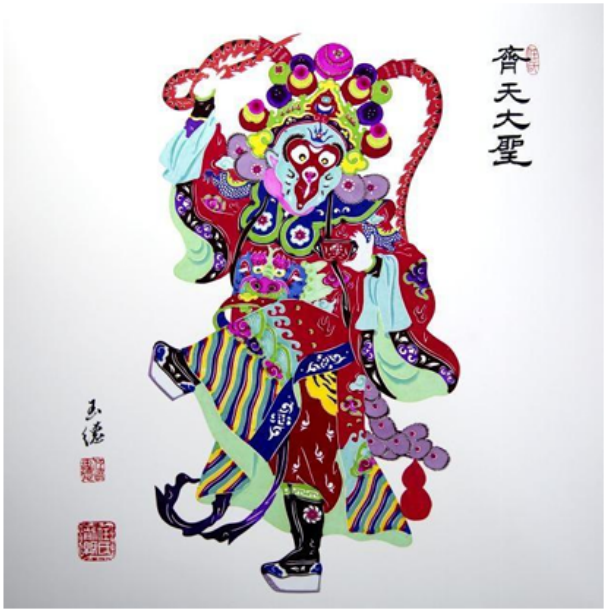

Figure 5. The *Great Sage Equal to Heaven by Ren Yude*, master paper-cutting artist from Yu County (bottom right)

In terms of traditional symbolic usage, Ren Yude's work is the richest and most exquisite. Employing the most representative and recognizable dotting technique characteristic of Yu County paper-cutting, his work exhibits extraordinarily vivid and rich color expression. His pieces incorporate a variety of traditional auspicious symbols such as cloud patterns, bats, and peonies, which are organically integrated with the image

of Sun Wukong, creating a strong atmosphere of traditional culture. The image generated by DALL·E similarly employs traditional elements like cloud patterns, bats, and ancient coins, but the details are somewhat simplified. The works generated by Doubao AI and Zhipu Qingyan are relatively minimalistic in their use of traditional symbols. Doubao AI's work includes almost no traditional auspicious symbols and mainly focuses on the depiction of Sun Wukong's figure itself; Zhipu Qingyan's work places greater emphasis on the exaggerated expression of Sun Wukong's facial and body lines, with traditional symbols largely weakened or omitted.

Regarding composition, in Ren Yude's work, Sun Wukong is positioned centrally with smooth body lines, where muscle definition is conveyed through variations in the density of the paper-cut lines. The sleeves and flowing ribbons flutter in the wind, adding vitality to the image. Influenced by various forms of traditional opera in his early years and having undergone extensive training in basic human poses after joining the Yu County paper-cutting workshop, Ren's works display vivid motion and strong expressiveness. The composition of the DALL·E-generated work is similar to Ren Yude's but falls slightly short in line delicacy and overall completeness of form. Doubao AI's work uses an asymmetrical composition with Sun Wukong's body slightly twisted, presenting a dynamic sense. Holding the golden staff, the staff's lines are simple yet powerful, forming a stable triangular structure with Sun Wukong's stance. This both conveys his agility and maintains a sense of stability. The paper-cut lines in the clothing are smooth, and the hems flutter in the wind, enhancing the image's dynamism and vitality. Zhipu Qingyan's work also employs an asymmetrical composition, with the facial and body lines of Sun Wukong greatly exaggerated. The lines intertwine and overlap, creating a complex and tension-filled structure that expresses Sun Wukong's wildness and strength.

Regarding line quality, Ren Yude's work features delicate and smooth lines with appropriate density variations, accurately depicting details such as Sun Wukong's muscle texture, clothing folds, and facial expressions. The flow and transitions of the lines are natural and smooth, imbued with a strong sense of rhythm and aesthetic harmony. In contrast, the lines in the DALL·E-generated image are relatively more regular but appear somewhat stiff in detail portrayal. The fluidity and naturalness of the lines do not match those of Ren Yude's work, with some connections between lines appearing unnatural. The lines in Doubao AI's work are simple yet powerful. Although less detailed than traditional works, they effectively outline the overall form of Sun Wukong. The variations in line thickness are moderate and convey a certain degree of artistic expressiveness. The lines in Zhipu Qingyan's work are bold and uninhibited. The exaggerated and distorted lines imbue the work with a raw vitality and wild beauty, with the twisting and interweaving of lines creating a unique visual effect.

In terms of preserving traditional visual elements, Ren Yude's work adheres most closely to conventional representations. Features such as the monkey face, monkey ears, and monkey tail are clearly defined. The character wears the phoenix-winged purple-gold crown, chainmail golden armor, and cloud-walking lotus-fiber shoes—details that faithfully reproduce Sun Wukong's classic literary attire. The facial expression is serious yet dignified, with a determined gaze that reflects Sun Wukong's bravery and intelligence. The DALL·E-generated work similarly adheres closely to traditional imagery, with recognizable monkey face and ears, as well as traditional headwear and chainmail armor, though the detailing is somewhat rougher. Doubao AI's design retains the fundamental monkey features—clearly identifiable monkey face and ears—and the phoenix-winged purple-gold crown and warrior clothing are also evident. However, the overall image is simplified, with less rich detail and an exaggerated facial expression. Zhipu Qingyan's work features a heavily exaggerated and distorted depiction of Sun Wukong. Although the basic features such as the monkey face and ears are discernible from the overall silhouette, the details are exaggerated to an extent that differs from traditional conceptions of Sun Wukong's image.

Regarding innovation in imagery, the AI-generated works exhibit certain personalized characteristics. The creations by DALL·E and Doubao AI introduce moderate innovative combinations in Sun Wukong's attire and surrounding symbols based on traditional imagery, imbuing the works with a degree of modernity. Doubao AI's piece, through its simple lines and asymmetrical composition, grants Sun Wukong a distinctive dynamic beauty and a sense of fashion. In contrast, Zhipu Qingyan's work demonstrates bolder innovation, employing exaggerated and distorted lines to create a strong visual impact that emphasizes Sun Wukong's wildness and strength, presenting a unique artistic style and personal expression. As a representative of traditional paper-cutting art, Ren Yude's work remains relatively conservative in innovation, strictly adhering to traditional craftsmanship and aesthetic norms, with an emphasis on the accurate reproduction of Sun Wukong's classic image.

A cross-comparative analysis of the four Sun Wukong paper-cutting pieces reveals that works by different creators each possess distinctive features in terms of symbolic language, stylistic characteristics, and the degree of fidelity in image design. Ren Yude's work fully embodies the essence of traditional paper-cutting art, holding profound artistic value and cultural significance in the use of symbols, shaping techniques, character portrayal, and cultural connotations. It serves as an important carrier for the inheritance of traditional paper-cutting art. The AI-generated works, on the other hand, to some extent reflect the fusion of modern technology and traditional art. DALL·E and Doubao AI's creations are relatively closer to traditional symbolic language and image design but are somewhat lacking in detailed modeling and artistic expressiveness. Zhipu Qingyan's work, through its exaggerated and distorted lines, presents a distinctive artistic style and innovative spirit, offering new ideas and possibilities for the modernization of traditional paper-cutting art. However, AI-generated works still show certain gaps compared to master artists' pieces in terms of cultural depth, craftsmanship refinement, and the inheritance of the essence of traditional art. Traditional paper-cutting emphasizes the creator's emotional investment, cultural understanding, and unique manual skills, whereas AI-generated works rely more heavily on algorithms and data, lacking the emotional warmth and cultural depth inherent in human-created art.

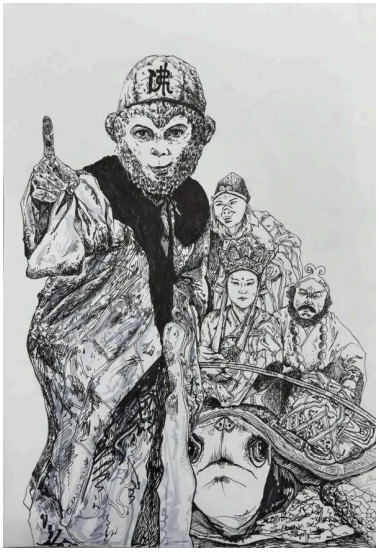

Figure 6. Zhang Xiaojiao, *Tongtian River* illustration design, 26 × 37 cm, carbon pencil on paper, 2024

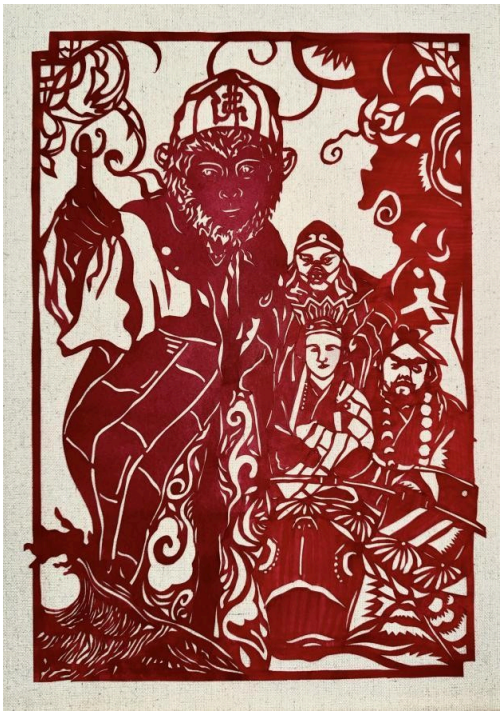

Figure 7. Zhang Xiaojiao, *Tongtian River* paper-cutting design, 26 × 37 cm, marker pen on sketch paper, 2024

4. Integration of illustration and paper-cutting: course practice and empirical assignments

4.1. Course logic and structure

Based on the characteristics of AI-generated images, a course was designed to combine the narrative features of paper-cutting with illustration design, exploring how traditional paper-cutting elements can be incorporated into modern illustration creation. The course employs a project-based teaching strategy to promote students' understanding and application of paper-cutting art. The core objective of the course is to guide students through practical exercises on how to use paper-cutting's symbolic language and techniques in illustration design, aiming to achieve effective storytelling and cultural transmission. The course design follows a progressive model of "from basics to practice, from modern to traditional", ensuring that students gradually master the narrative logic of illustration and are able to integrate traditional paper-cutting art with contemporary illustration design.

4.2. Case analysis

The course first required students to create an illustrative design based on the "*Tongtian River*" chapter from *Journey to the West*, testing their abilities in textual comprehension, image creativity, and fundamental illustration composition (see Figure 6). Subsequently, the course employed AI tools to transform the illustrations into paper-cutting style. During the use of AIGC tools, the course mainly selected Doubao and Zhipu Qingyan, which better conform to the traditional Chinese paper-cutting style, to assist in design. These platforms are widely applied in Chinese illustration and artistic creation, boasting powerful text-to-image generation capabilities capable of producing visuals aligned with traditional culture according to students' specific needs.

When generating paper-cutting style images, students first established a clear target scene: the four characters—Sun Wukong, Zhu Bajie, Sha Seng, and Tang Seng—sitting on the back of a giant turtle, crossing the *Tongtian River*. To ensure the generated images retained traditional paper-cutting elements, students used keywords such as "traditional Chinese paper-cutting style", "Sun Wukong", "turtle back", and "water ripple texture". These keywords guaranteed that the images preserved the symmetry, simplification, and symbolism characteristic of paper-cutting art while accurately presenting the classic scene from *Journey to the West*. By adjusting the keywords in detail, students further optimized the results. For example, to emphasize the turtle's shell and the flowing water, they added "turtle shell texture" and "*Tongtian River* water ripples" as supplementary keywords to ensure the images visually exhibited the layering and texture details consistent with the paper-cutting style (see Figure 7). Regarding the characters' expressions and actions, students fine-tuned the generation process based on each role's personality traits. Particularly, in facial expressions, clothing textures, and background elements, more traditional decorative symbols such as cloud motifs and floral patterns were incorporated to enhance the cultural depth and visual impact of the works. Moreover, the lines and structure of the images were optimized to ensure all details adhered to the bold lines and pattern connectivity fundamental to paper-cutting style, while the portrayal of Sun Wukong and his three disciples conformed to their classic literary images.

The final generated images not only successfully displayed the artistic features of traditional paper-cutting but also strengthened the emotional and narrative functions of the *Journey to the West* story in visual expression. Through this process, students learned not only how to use modern AIGC tools for creative work but also gained a profound understanding of how to achieve innovation and expression by integrating technology with traditional art. The outcomes of this course practice demonstrate the application potential of AIGC technology in paper-cutting art creation. It not only enhanced students' technical skills but also stimulated their reflection on traditional culture and innovative expression, opening new pathways for the inheritance and development of paper-cutting art.

5. Conclusion

In the face of the transformations brought by digital technology, the future development of paper-cutting art requires actively exploring the application of modern technologies while preserving its traditional cultural connotations. In this process, artists must not only emphasize technological innovation but also pay attention to the inheritance of artistic and cultural values. Digital media provide unprecedented expressive space for paper-cutting art, yet this transformation also demands that artists reconsider and express the cultural significance of paper-cutting from new perspectives.

In the future, the development of paper-cutting art will no longer rely solely on paper and scissors but will expand into broader virtual spaces and digital interactivity. Artists can explore new expressive forms of paper-cutting art through generative algorithms, 3D modeling, and other technological means, combining traditional paper-cutting elements with modern digital technology to create richer and more diverse works. Meanwhile, the global dissemination of paper-cutting art will be further promoted through digital platforms, especially among younger generations. This modernization of the art form helps stimulate their interest and identification with traditional culture. By adhering to the foundation of traditional cultural heritage while integrating innovative achievements from digital technology, works that align with modern aesthetics and possess cultural depth can be created. This represents not only a formal innovation in paper-cutting art but also a reexamination and expansion of the ways traditional culture is inherited.

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