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REVIEW ARTICLE

A STUDY ON THE GENERATION AND EXTRACTION OF ROCK ART LINE DRAWINGS

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ABSTRACT

Rock art, as a precious cultural heritage, carries the memory of ancient civilization and the essence of art. However, its preservation and research are facing great challenges, among which the extraction of rock art line drawings has become one of the important links. This paper discusses the technical method of edge detection for rock art line drawing extraction and its importance in rock art research. Through the introduction of rock art line drawing extraction examples, the complexity of rock art line drawing production and possible problems in image processing are discussed. It is hoped that the use of the computer as a tool to extract line drawings will ease the work of researchers.

KEYWORDS

Rock Art, Rock Art Line Drawings, Edge Detection

1. INTRODUCTION

Rock art has inestimable historical and cultural value as a precious heritage of ancient culture and art. With their colorful images and symbolic meanings, these ancient paintings present the concepts, beliefs and aesthetics of ancient civilizations, constructing a bridge of time that enables us to travel through the tunnel of time and get close to the cultural essence of ancient times. Rock art embody the human talent of abstraction, synthesis and imagination, depicting human economic and social activities, human concepts, beliefs and practices.[1] Its significance lies not only in its unique artistic expression, but also in the fact that it carries multilayered information about ancient societies, covering a wide range of topics, from social structures and religious ceremonies to technologies and lifestyles. Therefore, the preservation, study and transmission of rock art not only contribute to a deeper understanding of the essence of ancient civilizations, but also provide strong support for the continuity and diversity of human culture.

2. CONTEXT OF ROCK ART LINE DRAWING EXTRACTION

Rock art in China has only been discovered in large numbers for nearly a century, mainly from the 1950s to the early 21st century when a large number of rock art began to come into public view. Meanwhile the cultural heritage of rock art, which is huge in number, rich in content and diverse in subject matter, has aroused social concern, and for a while rock art tourism has become a new favorite of the tourism industry. Since the late 1980s, people began to gradually recognize the value behind the rock art and their preciousness. Due to natural and man-made factors, the destruction of rock art has become more and more serious in recent years, and the pressure for protection has also been increasing. Some precious rock arts are left without any protection measures, and are exposed to the wind and rain, and the natural weathering is getting worse, which brings problems to the protection of rock art. Therefore, the protection of rock painting cultural heritage has attracted great attention from the academic community, promoting the effective combination of digital humanities technology and rock art, so that the protection of rock art changes from the physical protection to the mode combing virtual and real protection [2].

In the context of rock art conservation, rock art data collection has become an important way to record, protect and study these precious cultural heritages. The collection and organization of rock art data generally includes three parts: photographs, rubbing and line drawings. In practice, the first two are relatively easy to master, while line drawings are difficult to complete without a high level of art skills. Rock art line drawings help to provide a clear and precise visualization of rock art. By highlighting the outline lines in the rock art, it is possible to observe and understand the patterns, symbols, and details of the rock art in a clearer way, which is crucial to the study and interpretation of the significance of the rock art. In the past, the following methods were mainly used to draw rock art line drawings: on-site direct depiction method, rubbing outline method and photo outline method. The direct depiction method refers to the use of professional artists to draw directly against the rock art on the spot, which is more difficult and time-consuming. This method is more difficult and cannot be completed by ordinary personnel. Rubbing outlining method refers using copy paper to outline the outline of ink along the rock paintings on the terrain under the guidance of professionals, and finally forms a line drawing. Although this method

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has small errors and high accuracy, it also has certain limitations. Photo sketch method means to enlarge the photo and then cover the top with copy paper to draw according to the pattern. This method has high cost and large error, and should not be used. At present, some people draw on foreign rock art line drawing method, using cellophane covered in the rock surface, with hardness water-based pen double hook line filling ink. This method requires the participation of many people, and good field operation weather. However, the error is large, so this way there exist certain difficulties.

The traditional method of making handmade line drawings is notable for its cumbersome and complex processes. Taking a simple rock art as an example, it takes at least ten hours to process it manually, and its low efficiency cannot be ignored. In addition, there are likely to be human omissions and errors in the process of processing, which are especially bad for the protection of rock paintings. For this reason, the introduction of computer technology, especially image processing technology, is particularly urgent and necessary.

The digital preservation and documentation are a key aspect of rock art research. Transforming rock art into digital form not only effectively compensates for the shortcomings of traditional handmade production, but also provides a reliable means for their permanent preservation in the digital domain. It is worth mentioning that traditional rock art is gradually affected by weathering and erosion under natural conditions, and digitization and the creation of high-quality line drawings can greatly ensure their lasting preservation and provide a sustainable basis for future research.

3. EDGE DETECTION

The key technology for line drawing extraction is edge detection, which is a very important branch of computer vision and is of great significance in many aspects such as target detection, image segmentation, feature extraction and so on. Generally speaking, the purpose of edge detection is to quickly and accurately locate and extract the edge contour information of objects in an image. In recent years, image edge detection has received extensive attention from researchers and a variety of different edge detection methods have been proposed.

Traditional edge detection methods obtain the edge map of an image by using the underlying features (color, luminance, gradient), and such methods obtain the edges of an image by locating and identifying the positions in the image where the features change drastically. Generally, they are divided into first-order edge detection algorithms and second-order edge detection algorithms according to the principle, in which the first-order edge detection algorithms mainly compute the gradient matrix of the image first through the appropriate differential operator, and then binarize the gradient matrix so as to obtain the edge of the image. The algorithms mainly include Robert operator, Sobel operator, Prewitt operator and so on. Second-order edge detection algorithm is to perform second-order differentiation of the image, which will produce a zero point. Local extreme points will be formed near the zero point that will be tested by setting the threshold. The algorithms mainly include LOG operator, DOG operator, Canny operator, etc.[3]. Edge detection algorithms based on artificial feature extraction sometimes have more accurate results, such as multi-scale feature detection algorithm[4], structured edge detection algorithm[5].

In recent years, with the continuous development of science and technology, the application of edge detection algorithms in various fields has shown vigorous vitality. In the field of automatic navigation, edge detection technology plays an indispensable role, which is used to recognize obstacles in the environment and provide reliable visual support for intelligent driving. And in the field of medical imaging, especially in the analysis of CT scans, MRI and other medical images, edge detection algorithms show a strong ability to accurately outline the outline of organs, and provide important reference for medical diagnosis. In addition to these modern technical fields, edge detection algorithms have also emerged in the study of history. Taking Dunhuang frescoes, portrait stone rubbings and rock art for example, these ancient artifacts and rock art have a lot in common. In recent years, scholars have begun to introduce edge detection technology into the study of Dunhuang frescoes and portrait stone rubbings, through which the outline lines of the works can be clearly extracted, and the resulting line drawings are very close to the original image, which undoubtedly provides an efficient and reliable technical means for the extraction of line drawings of rock art. Therefore, we will try to use the edge detection technique to extract the line drawings of the human “Venus” rock art and large hunting rock art in the following.

4. EXAMPLE OF EXTRACTING LINE DRAWINGS FROM ROCK ART

Figure 1 shows the detailed process of rock art line drawing extraction. First of all, in the selection of rock art pictures, two basic requirements need to be met: one is that the whole photo should be under the same lighting environment to ensure the consistency of the subsequent processing; the second is that the rock art pattern in the photo needs to be clearly recognizable and is free of sundry obstructions to ensure the accuracy of the extraction. After selecting suitable rock art pictures, the first step is to carry out grayscale processing, which converts color images into grayscale images to simplify the subsequent processing. Next, thresholding is performed to convert the grayscale image into a binary image by setting a suitable threshold to highlight the outline of the rock art. Since rock art images are often accompanied by large noise, in order to reduce the impact of noise, Gaussian filtering is used for noise reduction, thus making the image clearer. Subsequently, an edge detection algorithm is applied to accurately outline the contour lines of the Rock art. On this basis, for the possible mutilations or voids in the image, we use hole-filling to repair them and ensure the integrity of the line drawings. However, the rock art line drawing may not be satisfactory during the practical operation process. For this reason, repeated operations and adjustments will be made to obtain the ideal rock art line drawing that meets the expectations and ensures the accuracy and quality of the extraction results.

The “Venus” rock art is located on the northern slopes of Zhongwei City, Ningxia Hui Autonomous Region, China. This rock art is a nude figure of a woman with full breasts and a big belly, which is a unique humanoid rock art with high research value. Therefore, according to the above process, the line drawing of the rock art called “Venus” is extracted. It was first grayscaled and then processed with the same threshold setting and Gaussian noise reduction procedure. Then, five different edge detection kernels, Canny, Roberts, Prewitt, Sobel, and Laplacian, were applied, followed by the corresponding filtering and hole processing to obtain the results of the first line drawing extraction,

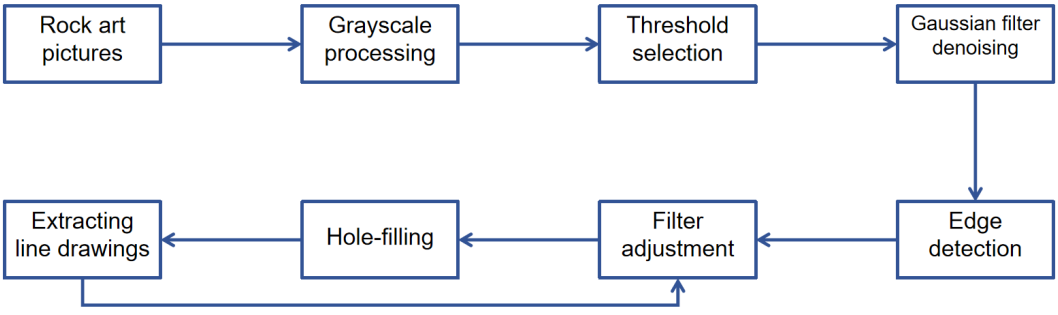

Figure 1: Flowchart of Line Drawing Extraction

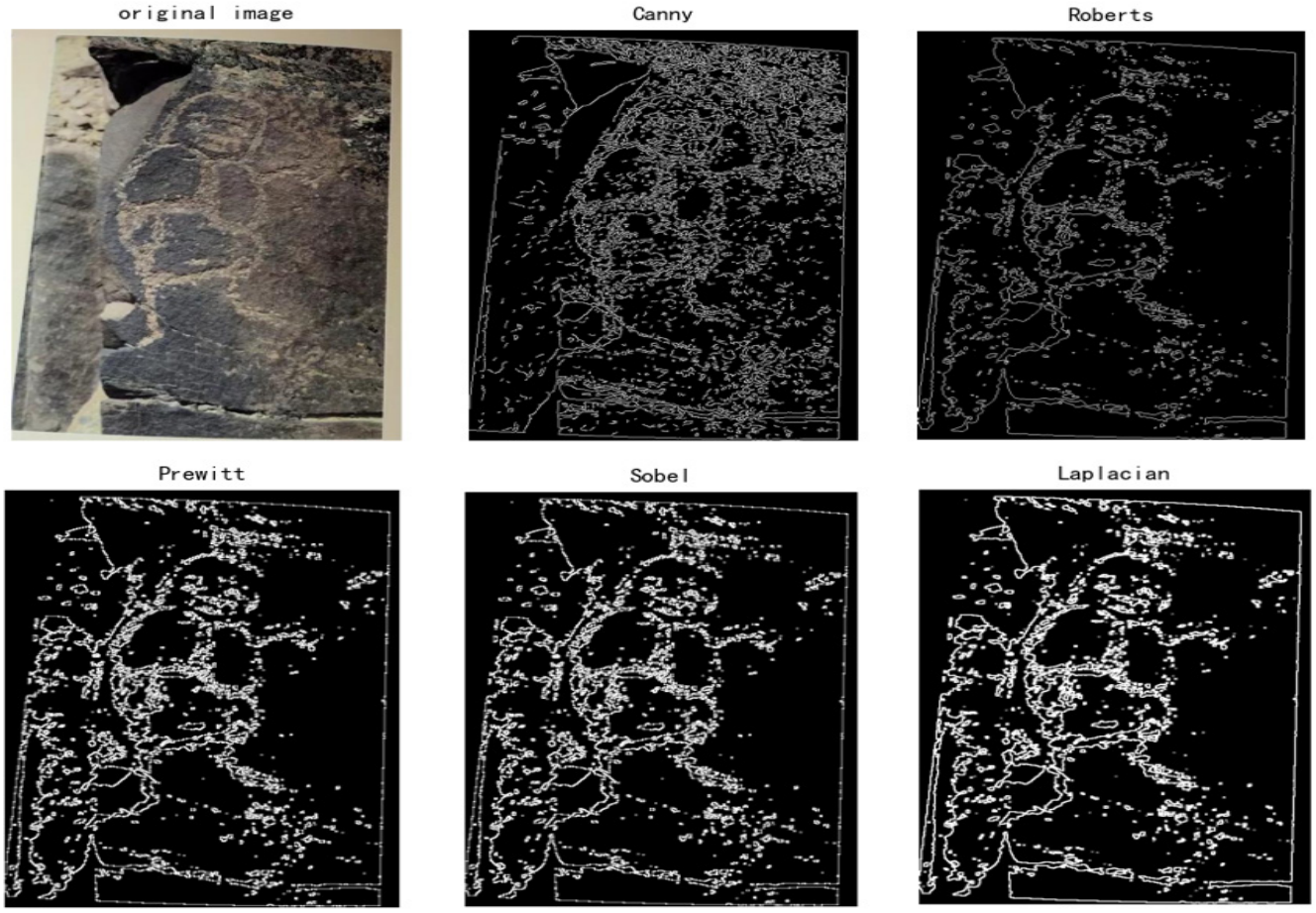

Figure 2: Results After One Processing with Different Operators

as shown in Fig. 2. It is worth pointing out that the contours of the line drawings obtained after the initial processing present diverse features. Specifically, the line drawings obtained using the Canny operator appear unclear, which can be attributed to the characteristics of this operator; in contrast, the results obtained using the Roberts operator are darker, with a higher degree of blurring of the contours. The results obtained with the remaining three operators do not show significant differences in the contour characteristics. However, it is worth mentioning that the Laplacian operator gives a clearer outline and a more complete retention of details.

By applying the Laplacian operator, we obtained a line drawing of the "Venus", which presents a high degree of clarity and accurate contour features. Given this, we chose this result for multiple operations to adjust the filtering range and to exclude pits and redundant areas in the image. In Figure 3, we present the "Venus" line drawing after multiple operations, which resulted in a clearer outline and successfully removed redundant and invalid areas, thus preserving the critical edge information of the Venus Rock art. It is worth emphasizing that obvious rock cracks can still be observed in the processed results, and although these cracks are inherently removable, we have chosen to retain them as they may provide important information to researchers. In addition, the large pit point may be considered a small rock art symbol on the rock and was therefore also retained. In view of the special nature of the rock art, most of the outline is actually made up of the pit points. If the reverse phase treatment and the common white background black lines are used, a clear effect will not be obtained. Therefore, we chose to use black and white lines for display to better present the details and outline characteristics of the rock art.

Complex line drawings of large rock art are cumbersome and time-consuming to process manually, so it is especially important to use computers for line drawing processing. The rock art image below contains many contents, including characters, people riding, archery, animals and many other clear patterns. In the same light, no shadows and no debris blocking, which meets the basic principles of line drawing

Figure 3: Multi-Processing Diagram of "Venus".

processing, is suitable for line drawing extraction. The picture will be processed in accordance with the process of line drawing extraction, not to show the specific process here. The results of the extraction of line drawings are shown in Figure 4 that used white bottom black lines.Comparing the original images of the Rock art with the computer-processed line drawings, it can be observed that the line drawings are excellent in retaining the key information in the rock art pictures.

Figure 4: Line Drawing of a Big Game Map

In particular, in the upper left corner of the line drawing, the outline of the pattern of a pattern of human archery on horseback is drawn very completely; while in the lower left corner, the patterns of upright human figures and animals are also well preserved. In the central area, where the motifs are numerous and complex, the line drawing is able to show each outline clearly, although there is a degree of blending. Consideration may need to be given to filling them in with black pigment to achieve a better visual effect.

However, at the top-of-the-line drawing, the pattern of the sheep was partially missing, especially because the legs and head of the sheep were not fully preserved. Meanwhile, in the far-right area of the image, the phenomenon of mixing is more prominent, and it is difficult to clearly identify the specific content. This suggests that the results of computer processing may not be satisfactory in some cases, and therefore manual intervention and supplementation are needed to ensure the accurate presentation and understanding of the rock art.

These two-rock art were processed by the computer in a single pass in less than five seconds, which significantly reduces the time compared to manually drawing line drawings. However, we can also observe that the computerized results are not flawless. There is a situation of mixing and missing outline, which requires manual intervention and repair according to the actual situation to achieve a more perfect visual effect, so as to more effectively meet the needs of researchers. This process is not just a simple application of technology, but also an effective combination of artificial intelligence and human expertise, offering new methods and possibilities for rock art research.

5. CHALLENGES AND SOLUTIONS FOR ROCK ART LINE DRAWING EXTRACTION

5.1 Rock Art Mutilated

Due to the influence of natural environment, human damage and other factors, the rock art itself often presents a defective state, and this defect constitutes a considerable challenge for the extraction of line drawings. Similarly, the problem of defects often exists in the extraction of line drawings of other cultural relics, such as Dunhuang frescoes[6] and portrait stone rubbings[7]. Hole-filling techniques play an extremely important role in many fields, especially in image processing, due to their efficiency and adaptability. The holes can be surrounded by foreground pixels, so the hole-filling technique is also a kind of region filling technique.

Figure 5: Extraction Problems Due to Lighting Conditions

In the actual processing of rock art images, whether to fill and complete is a thorny problem. Considering the special characteristics of rock art and its long history, excessive reliance on automated filling methods may lead to the addition of parts to rock painting images that do not exist, which may mislead the researchers' analysis and interpretation. Therefore, it is necessary to use manual intervention, including threshold adjustment, region segmentation, noise setting and other steps, and the specific operation needs to be adjusted and implemented according to the characteristics of different rock art. This method ensures that more accurate and realistic results can be obtained during the extraction of rock art line drawings, which provides a reliable data base for the subsequent research work.

5.2 Photography and Selection of Rock Art Images

The complexity of the rock art, the geometry of the stone wall surface, the lighting conditions and the color all have a significant influence on the extraction process of line drawing. In rock art line drawing extraction, the high quality of the experimental images is very urgent, especially the need to ensure a high degree of consistency in image quality when processing rock art photos by computer. For this reason, vertical or parallel shooting should be chosen to ensure the accuracy of the patterns and keep the extracted outlines free from distortion, so as to obtain a more excellent visual effect.

5.3 Options for Dealing with Uneven Illumination

The phenomenon of shading in rock art images may lead to segmentation during the extraction process. As shown in Fig. 5, for example, one side of the tiger pattern in the rock art that is illuminated by sunlight contrasts sharply with the other side that is in the shade. During the processing, there is an imbalance in the noise on both sides, which leads to the fact that the outline cannot be completely and accurately extracted no matter what kind of operation is taken. The solution to this problem is to ensure that the entire rock art image is photographed under uniform lighting conditions, i.e., either all of it is in shadow or all of it is illuminated by sunlight.

However, given the treacherous geography in which most of the rock art are located, reacquiring the photographs becomes difficult. Therefore, it is crucial to introduce new techniques to optimize the line drawing extraction process. Currently, the dynamic range adjustment technique has become a method of great interest for the processing of shadows and illumination of images. This technique has the ability to make rock art images show clear outlines under different lighting conditions, which makes it easier to extract line drawings. The results of this research will be one of the important directions for future research.

5.4 Rock Art Stacking

Rock art often presents a rich variety of patterns, which may intertwine and overlap with each other, and even exhibit complex layering, thus posing considerable challenges to the accurate extraction of line drawings. The complexity of the rock art surface makes it complicated to distinguish the contours of each pattern. Meanwhile it is necessary to consider the possible boundary blur, cross connection and so on, which makes the extraction of rock art line drawings quite challenging and require the full use of advanced image processing techniques. For the complex overlapping situation, techniques such as regional growth and edge connection can be applied to separate and recognize the intertwined patterns. Considering the historical specificity of rock art, manual intervention is also an indispensable part. Combined with the expertise of rock art researchers, processing solutions can be customized according to the specific context and historical period of the rock art in order to preserve and highlight their unique value and information. Through the combined use of advanced image processing techniques, specialized knowledge and manual intervention, the difficulties posed by complex overlapping patterns can be overcome to obtain accurate and complete line drawing results.

6. CONCLUSION

Rock art images are numerous. This study aims to reduce the workload of researchers by using computer technology as a medium for line drawing a large number of rock art images. Firstly, the rock art images were pre-processed, followed by line drawing extraction of the rock art using traditional edge detection algorithms. A series of results were obtained and presented. Most of the line drawings can effectively highlight the outlines of the rock art, but there are still some local unsatisfactory aspects in the processed images, such as the ambiguity and absence of information. In view of the heterogeneity of rock art images, different rock painting images contain various noise characteristics and situations of absence and superposition. Thus, in rock art image processing, it is necessary to adopt corresponding processing schemes and methods for different rock art images. One of the future research directions is to apply the image understanding technology in the field of artificial intelligence to the research of rock painting image line drawing, so as to obtain clearer rock art information and more coherent line presentation with the help of artificial intelligence technology. This exploration is expected to provide more efficient and accurate tools and methods for rock art research and promote the development of rock art image processing.

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