

Restoration Logic and Digital Research on Damaged Images of Traditional Murals: With Reference to Song, Yuan, and Ming Murals in Southern Shanxi

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Abstract

Investigate the restoration logic of damaged traditional mural images and its link to digital research on Song, Yuan, and Ming Murals in Southern Shanxi. Restoration should not be seen merely as a technical problem of image completion; rather, based on iconographic structure, pictorial order, material evidence and conservation ethics, the mural needs to be reconstructed. Based on research in murals, restoration theory and new studies on digital image repair, this paper will explore how damaged mural pictures can be interpreted through a series of steps: documentation, structural analysis, controlled inference and digital visualisation. Digital restoration can also serve as a research tool for the study of historical objects, but it should not replace that study. Southern Shanxi murals are narrative works that integrate architectural spaces and regional pictorial habits; thus, the logic of restoration should consider both the visual grammar of the pictures and the limits of scholarly reconstruction. Therefore, the paper takes digital restoration as a necessary, reversible and interpretive way of heritage research.

Keywords

Mural restoration; digital heritage; southern Shanxi murals; image reconstruction; conservation theory; wall painting.

1. Introduction

Traditional mural paintings are more likely to be damaged by ageing, climate change, structural problems, human activities and previous restoration work. Losses of contour, colour, surface continuity and narrative details may make it difficult to understand a mural even if some large parts are still available. Thus, the restoration of damaged mural images should aim to supplement the missing parts visually as well. It is an interpretive problem that requires decisions on what can be inferred, what should remain unknown, and how restored visibility relates to the historical integrity of the object.

The Song, Yuan and Ming mural traditions in southern Shanxi are particularly affected by this problem. Figures in these works are often accompanied by many spaces, buildings, rituals, and so on. Damage to a picture is thus a loss that is not only material but also in meaning. A missing border, a broken halo or an erased line of gesture will be in conflict with the whole work.

This paper studies the restoration logic of damaged traditional mural images and the prospects for digital research based on Song, Yuan and Ming murals in southern Shanxi. The order of restoration should follow that of historical reading to visual inference and from visual inference to digitally assisted reconstruction; the reverse is not appropriate. Based on the above, this paper will introduce the documentary background of Shanxi mural research, the main logic of restoration, the role of digital technology, and a reconstruction framework for interpreting damage and reconstruction.

2. Documentary Background of Southern Shanxi Murals

Start learning about restoration logic by reading documents. The survey and digital documentation project on endangered temple wall paintings in Shanxi have shown that recording murals includes not only preservation photography but also understanding the architectural environment and condition mapping of the murals in relation to the built environment [1]. This is because the damage cannot be understood without the original conditions under which it was displayed, such as the hall, altar arrangement, viewing angle and ritual purpose. For example, the location of a damaged figure in relation to the altar, entrance, adjacent panels and viewing route can help determine whether the missing part belongs to the ritual hierarchy, narrative sequence or architectural boundary.

Research by art historians has also classified the Shanxi wall paintings as a whole part of the area's visual culture rather than as individual works of art. Beyond Silk points out that temple murals in north China, and outstanding examples from Shanxi, are important works of art in the history of painting that should be studied in the context of regional painting networks, media conditions and space [2]. Therefore, restoration studies need to use both local fragments and historical knowledge of style, composition and pictorial habits in their work of image repair. Region comparison at the level of image reconstruction can provide specific references for figure proportions, costume patterns, architectural frames, repeated ornaments and compositional symmetry.

Research on Kaihua temple also shows that the murals in Shanxi combine narration, religion and daily life in pictures [3]. The above-mentioned coexistence is required for the logic of restoration because the damaged area may contain not only decorative materials but also gestures, social environments, ranks and ritual orders. Therefore, in reconstruction, narrative syntax should be combined with contour relations, colour organisation, figure gestures and ritual order.

A study of the geographical distribution of murals in Shanxi also shows that there are diverse regions from the Song, Liao and Jin Dynasties, and their settings and picture-writing methods vary considerably [4]. Therefore, there is no single restoration template for all of the Shanxi Murals. In other words, the composition of figures, architectural framing, ritual emphasis and regional pictorial conventions will directly influence which reconstruction is visually harmonious and historically accurate for a specific site. Although the relatively connected visual tradition has some links, the restoration logic should still be site-specific; otherwise, the connection among the wall, image, iconography and damage pattern would be lost.

Together, these studies suggest that the mural should be seen as a space-time document first and only then as a damaged picture. Only at this documentary level will the restoration avoid reducing the historical difference to a general digital reproduction.

The type of the evidence may be chronological, spatial or material. Chronological evidence refers to the historical order of construction, repainting, repair and damage; spatial evidence refers to the connection among mural panels, architectural bays, altars, entrances and viewing routes. Material evidence refers to the preserved pigment layer, plaster boundary, tool mark, etc., of a previous alteration. These forms of evidence should not be considered interchangeable. A repeated costume pattern can be viewed as a type of decoration, but it is impossible to determine the particular identity or movement of a missing person from this alone. Comparison with another temple can also show regional norms but does not confirm that the two mural programmes were produced by the same workshop. Therefore, the hierarchy of evidence employed in responsible reconstruction should be direct physical evidence, site-specific spatial and iconographic comparisons, regional stylistic analogies, and finally general visual similarities. Evidence at the lower levels should be given more weight than visually plausible

but less verifiable comparisons. The above hierarchy can help prevent the substitution of historical interpretation with visual plausibility in digital reconstruction [1-4].

3. Restoration Logic of Damaged Mural Images

First, there is no falsification: the lacunae are not empty spaces for free invention. According to Brandi's theory of restoration, the intervention should respect the historical conditions and aesthetic unity of the work, and avoid falsifying what can no longer be reliably known [5]. For damaged murals, this means that the restoration should make the damaged parts understandable without pretending that all the lost sections can be fully recovered.

The second is a structure-of-writing approach. Organise a mural according to contour, rhythm, scale, direction of gaze, colour harmony and composition. Damage will break these connections, and thus reconstruction cannot be carried out without considering the original visual relationships. Classical image inpainting research by Bertalmio and others is related to this because it shows how to extend edges and local structure to guide the filling of missing areas [6]. Heritage murals are not typical digital pictures; however, the basic idea is still the same: for image continuity, structure comes first, and decorative freedom follows.

The third is context-aware completion rather than automatic addition. Criminisi, Pérez and Toyama show that region filling benefits from exemplar-based logic, and information is extended from suitable surrounding areas rather than added arbitrarily [7]. In art history, the above logic is referred to as mural research. Missing sections should be reconstructed based on verified adjacent patterns, mirrored compositional systems, repeated costume units, architectural motifs and known iconographic sequences, and not according to contemporary fashion.

The fourth rule refers to the scale and meaning of the damaged area. Guillemot and Le Meur have presented an introduction to image inpainting generally, and the problems of restoration vary according to whether the missing information is texture, a large-scale structural gap, semantic content, or mixed damage [8]. Traditional murals have the same types of restoration problems. A small flake loss at the edge of a robe is not methodologically equivalent to the absence of a face, an attendant figure or a ritual attribute. Therefore, the logic of restoration should differ according to the scale and importance of the missing part.

The fifth rule is inferential restraint. For the murals in Southern Shanxi, many of the compositions are sufficiently organised to allow for the meticulous addition of borders, haloes, throne edges, architectural frames and repeated ornaments. Compound losses, such as changes in particular facial expressions, hand gestures, inscriptions or narrative events, cannot be addressed by altering only visual symmetry. Restoration should distinguish between probable restorations and speculative reconstructions, and digital visualisation should be used as a research tool rather than an unmarked fiction.

The sixth rule is multilayered interpretation. Over time, the murals have been damaged by abrasion, smoke, water, structural movement, repainting and loss of plaster. What appears to be a single missing image may actually contain multiple historical episodes of alteration. Thus, the logic of restoration should treat the damaged part as evidence rather than merely an omission. The digital image should not erase the historical record of damage before it has been analysed as part of the material history of the work.

Together, the six rules are a set of recovery steps. First, identify the material and historical status of the damaged area; then, reconstruct the interrupted structural relationships, select contextually verified references, evaluate the scale and semantic importance of the loss, grade the certainty of the proposed completion, and finally preserve visible traces of historical alteration. We do not hope to create a beautiful picture at all costs; instead, we want to explore

the understandable connections and track what has been remembered, what has been inferred, and what remains unknown.

4. Digital Research Pathways

Digital tools are only effective if they meet the criteria listed above. Research on the digitally aided preservation and restoration of a fragmented mural in a Tang tomb shows that, by documenting displaced fragments and visualising reconstruction options, digital methods can support conservation without altering the remaining pictorial evidence directly [9]. The reasons listed above are the main reasons for using digital research in mural restoration.

Recently, research in digital restoration has also found that structure-guided methods are very suitable for heritage images. A typical result of the 2025 Heritage Science study on mural restoration using the combination of edge-guided and multi-scale spatial features is that contour guidance, spatial hierarchy and the preservation of visually coherent boundaries in damaged wall paintings should be taken into account [10]. Traditional murals should also be restored by adding colour to lines and shapes and pictorial arrangements first.

Similarly, the 2026 study on ancient Jiangnan murals also proposes proxy learning and structural guidance for restoration scenarios without paired reference images [11]. These methods can provide support for digital restoration research on Southern Shanxi murals, but their application should still be approved by experts.

At the same time, digital research should not be taken as the creation of automatic truth. Algos can extend lines and recognise patterns, but they fail to recognise iconography, ritual hierarchy, workshop customs, or the symbolic significance of compositional omission. A digitally plausible image is not necessarily historically accurate. Therefore, digital restoration in heritage research should follow a six-step process: (1) documentation, (2) condition diagnosis, (3) structural analysis, (4) historical comparison, (5) reversible digital reconstruction, and (6) scholarly review. Each stage is limited by the preceding one: documentation provides an evidential basis, condition diagnosis determines the characteristics of the damage, structural and historical analysis establish acceptable reconstruction hypotheses, digital reconstruction visualises these hypotheses, and scholarly review verifies their historical accuracy.

The above workflow is particularly necessary for the Southern Shanxi case due to the high level of organisation of its mural programmes. The placement of the figures shown, repetition of costumes, framing devices and directional movements are generally sufficient to support a partial reconstruction, but not enough evidence for a full imaginative repainting. Digital methods are most convincing when they explicitly indicate the degree of certainty and do not conceal uncertainty in a visually smooth way.

Thus, the content of the digital research will have epistemic and practical values. This is a relatively stable environment for the hypothesis test and comparison of different editions, and the supporting evidence for each restoration decision is clear. Therefore, the best digital restoration is not the one that looks most perfect at first glance, but rather the one that shows clearly how and why a completion was proposed.

5. Reconstruction Framework for Southern Shanxi Murals

A feasible reconstruction framework for damaged murals in southern Shanxi consists of the following five sequential stages: (1) documentary stabilisation, (2) iconographic identification, (3) structural mapping, (4) graded reconstruction and (5) reversible digital display. The first is documentary stabilisation: high-quality imaging, condition recording, spatial registration, and differentiation of original paint from later intervention and material loss [1]. The second is iconographic identification based on the analysis of surviving motifs and compositional roles,

as well as comparison with related mural programmes in Shanxi [2-4]. The third is the structural mapping of lines, figure axes, framing systems and repeated ornamental units that can provide a cautious end.

The fourth is the graded reconstruction. Small losses that do not affect continuity can be handled by restrained completion of contours and local colour relationships; large losses should be divided into probable, possible and indeterminate zones. The study of the Kaihua Temple and the entire Shanxi Mural Survey together show why this graded method is needed: even in highly organised religious paintings, narrative details and social imagery are often essential to the meaning, and they cannot be responsibly restored by general pattern extension alone [3, 4].

The fifth is a reversible digital display. Digital methods of inpainting and structure-guided restoration can be used to build alternative completion models here [6-8, 10-11]. The model should be displayed in a manner that does not make it unclear what kind of evidence it is. That is to say, a responsible digital display should clearly distinguish between the original and the reconstructed parts. The five stages are in a fixed order. Reconstruction should not start until documentary, iconographic and structural evidence have been analysed, and every digitally created part must be traceable back to its evidence and degree of certainty.

The two are classified as the reason for restoration and visual enhancement, respectively. Restoration logic determines what is needed by the image to restore readability within historically justified bounds. At the same time, beautification also wants to know what will please the public at present. The two aims are not the same. Brandi's theory is still applicable to help maintain visual harmony without achieving an all-encompassing false historical totality [5].

Murals in Southern Shanxi are a typical case of this. Murals in this area often have rich stories and rhythmic lines, and they are frequently intertwined with sacred and secular visual languages. If these particular pictorial systems are not included in the digital reconstruction, it will be reduced to a general computational smoothness. Therefore, the responsible digital study should be based on local art history and use modern tools simultaneously.

The framework finally proposes an extended research direction. Digital restoration can support exhibitions and, at the same time, provide research materials for workshop practice, regional composition and damage patterns. Thus, the reconstruction should be shown as documented interpretation rather than an exact reproduction of the original image. If digital reconstruction is to be carried out, its output should serve not only as a visual presentation but also as a documented record of the evidence, reasoning, uncertainty and historical possibilities in the reconstruction process.

6. Conclusion

The restoration of damaged traditional murals is a problem of logic before it is a problem of software. For the murals of the Song, Yuan and Ming Dynasties in Southern Shanxi, reconstruction should be based on documentary evidence, pictorial structure, iconographic knowledge and conservation ethics. Only on this basis can digital methods be applied usefully to the study of lost or damaged pictures.

Digital restoration is most appropriate when it is still in a critical state, reversible, and explicitly states the degree of certainty. Do not add missing parts of the mural images arbitrarily in the restoration work; otherwise, the most serious problem in restoration will be to create falsehoods by over-clarification.

Therefore, the future direction of research in digital murals will be to integrate art history, conservation science and computer imaging in an open-interpretation system. Thus, we can

improve the reading experience for the public and promote further research, while also protecting the historical value of the damaged mural.

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