The Role of Artificial Intelligence in Art Restoration

Author's Statement

This work was completed in Interpretation and Argument (76-101), Dr. Chad Szalkowski-Ference's foundational, inquiry-driven writing course that introduces students to a variety of strategies for making compositional decisions in writing and communication. For this assignment, called a "Contribution Essay", we were asked to conduct research on an issue of our choice and produce a research article that contributes to an ongoing academic conversation.

As someone who is passionate about AI, I wanted to explore how AI could solve problems in a field where the development of AI technologies is still nascent. Through this project, I discovered how modern AI algorithms can uncover stories of the past by restoring damaged paintings, and had fun testing AI art restoration software on some famous paintings. This project has fueled my passion for AI research and strengthened my belief that AI does not replace artists, but instead complements them. I am very grateful to my faculty mentor Dr. Chad Szalkowski-Ference and co-editor Dr. Alan Kohler for their invaluable guidance in this learning journey!

Glenda

Abstract

Art restoration, the practice of returning a damaged artwork to its original condition, is challenging: each artwork requires a unique treatment and complex ethical boundaries may be crossed. However, this field can be transformed by today's artificial intelligence (AI) algorithms, which currently excel in artistic tasks. Hence, this research aims to elucidate the role of AI in art restoration, specifically in restoring damaged paintings. To achieve this, an AI image enhancer web application was tested on images of three damaged paintings, with its digital reconstructions benchmarked against the actual restorations using various technical and aesthetic metrics. Results show that AI currently plays the role of an assistant in the analysis stage of art restoration: while AI can propose feasible intervention methods and produce digital reconstructions to aid art restorers in restoration (accelerating, improving accuracy and lowering costs), it cannot guide them in navigating complex ethical boundaries. Art restorers are still responsible for striking the balance between improving an artwork's legibility and respecting the original creation. These findings showcase the potential of AI to the artistic and historical communities, spurring further research into developing more effective AI algorithms.

Introduction

Throughout history, countless paintings have been destroyed or lost due to war, terrorism and natural disasters. Such catastrophic events erase the stories told by these paintings, cripple our interpretation of them and lead to a loss of our cultural heritage. Nevertheless, the damage inflicted on these beautiful but fragile artworks can be reversed through art restoration, the practice of returning an artwork to its original condition.

Art restoration generally involves two main stages: analysis and restoration. In the analysis stage, art restorers determine the loci, extent and cause of damage, as well as devise possible strategies for intervention. These strategies are then implemented in the restoration stage, where cleaning, inpainting and varnishing are performed on the paintings. However, art restoration is a highly complex process – its success depends heavily on decisions made in the analysis stage, which demands extreme precision and artistic skill. If the wrong intervention is proposed after analysis, it may not only fail to repair the damage, but also further destroy the painting. This creates exhaustive cycles of analysis and restoration, making art restoration expensive, labor-intensive and time-consuming.

Recent developments in artificial intelligence (AI) have enabled it to perform tasks with high precision and efficiency, and even excel in artistic tasks such as image generation. Hence, one would wonder if AI has the potential to transform the field of art restoration, especially in the analysis stage. If implemented feasibly, AI can propose feasible intervention methods and digital reconstructions for art restorers to implement in the actual restoration. This can significantly accelerate, minimize costs and increase the success rate of art restoration. However, developments of AI in this field are still nascent. Therefore, this research aims to discover how AI can solve existing challenges in the analysis stage of art restoration, and its effectiveness in doing so. This

would aid art restorers in their line of work, benefiting both the artistic and historical communities.

Literature Review

Challenges Faced in the Analysis Stage of Art Restoration

One identified challenge in the analysis stage of art restoration is the complexity of artworks. Each damaged artwork differs greatly in terms of its object type, cultural context, original materiality and aesthetic integrity (Scott 86), thus requiring a unique treatment. Moreover, art restorers may not possess perfect knowledge of how the artworks' materials might change with age, respond to different environmental conditions, or react to potential treatments (Learner 5). Consequently, they may struggle to decide on the most appropriate treatment from limited known options, or worse, apply an inappropriate treatment that further damages the artwork. Hence, these complexities significantly delay the restoration process, hindering art restorers in determining the most effective treatment.

Besides managing the complexity of artworks, art restorers also have to navigate a challenging ethical boundary: respecting the original creation. Throughout history, art restoration has demanded the preservation of a monument's aesthetic and historic value, as well as respect for the original material (Scott 86). Similarly, Van Saaze's two fundamental beliefs of conservation – preserving the integrity of the object and that the best means to achieve this is through the application of science– align with this principle (Van Saaze 41). This means that art restorers are often encouraged to improve an artwork's legibility through scientific techniques, but must cease action when an artwork begins to lose its artist's original intent and style. But when is this line crossed? Insights on how far an artwork should be restored vary greatly among individuals. As a result, most restored artworks, no matter how beautiful or complete they are, will invoke some form of criticism. For instance, a Spanish art restorer was so focused on fixing a century-old flaked

"ecce homo" fresco of Jesus that she misfortunately disfigured him with a monkey-like appearance, angering the artistic and religious communities (Minder). Therefore, on top of the already Herculean task of determining the most appropriate treatment, art restorers are also forced to make difficult practical compromises and confront ethical dilemmas in their work.

Current Applications of AI in Art Restoration

In 2021, researchers at the Rijksmuseum in Amsterdam used AI to restore the missing edges of a famous painting, Rembrandt's The Night Watch (Criddle). Similarly, a year later, researchers from Google and the Belvedere Museum digitally restored a lost trio of Klimt's paintings with AI (Aspuru).

The abovementioned AI algorithms are usually generative adversarial networks (GANs), popular deep learning architectures for generative tasks. A GAN consists of two networks – the generator, which generates images, and the discriminator, which predicts if an image is real or synthetic. During training, the two networks compete against each other in a zero-sum game. The discriminator learns to make better predictions on the authenticity of a given image, while the generator learns to generate better images to fool the discriminator. Overall, this enables the GAN to generate realistic images of high fidelity to the original dataset and excel in artistic tasks.

In the context of art restoration, these networks are first trained on existing artworks to learn the involved artist's style. The AI mentioned in Criddle's article was trained on two images – a high-resolution scan of the original painting, and a painted copy. Likewise, the other group of researchers trained their algorithm on 80 images of Klimt's work and 100,000 works by other artists to learn Klimt's coloring style. Training on extensive samples of artworks enables AI algorithms to learn rich representations of artwork features, so they can recognize unique attributes of a damaged artwork and recommend targeted treatment options in situ. This eliminates the need

for extensive on-site surveys, greatly accelerating the restoration process. However, one limitation of these algorithms is that they require large datasets and extensive fine-tuning to achieve a high performance. From Figure 1, researchers have to photograph thousands of artworks to collect sufficient training data, which is labor-intensive.

Figure 1. Collecting Training Images for AI Algorithms

After training, the AI algorithms then generate a reconstruction of the damaged artwork. Digital reconstruction gives art restorers a preview of possible restorations they can attempt, which can be further discussed with art historians. In the past, as their alterations were set in stone, art restorers struggled to correct mistakes in their work, especially those that were already irreversible. However, with AI, they can reach an agreement on the desired restoration before implementing alterations, significantly reducing the chances of errors. Hence, AI can increase the success rate of art restoration.

Figure 2. Digitally Reconstructed Klimt Paintings

However, these AI algorithms may not be entirely accurate in their interpretation of the artworks. For instance, the algorithm in Aspuru's text initially suggested the wrong colors for what scholars knew about Klimt, so the researchers had to reference how the paintings were described from other sources and guide the AI towards colors they believed to make more sense (Aspuru). From this example, this developmental stage relies heavily on the researchers' own artistic intuitions, which can be highly subjective. Moreover, there are currently no benchmarks for evaluating the outputs of these algorithms. In Aspuru's article, a historian specializing in Austrian and German art found the AI's reconstructions "more like cartoons" of Klimt paintings, which "lacked the nuanced tonal transitions Klimt is known for" (Aspuru). Contrastingly, the developers argued that there could be a possibility that Klimt used those suggested colors. Both perspectives are plausible, but it is not known which is true. Therefore, art restorers and the artistic community have to engage in open discussions about the digital reconstructions generated by AI algorithms, modifying them until an agreement is reached.

Section Summary

To conclude this section, in the analysis stage of art restoration, art restorers are often challenged by the complexity of damaged artworks and the ethical boundary of respecting the original creation. However, current applications of AI in art restoration, which usually involve the use of GANs, can help art restorers overcome these challenges by creating a digital reconstruction of the damaged artwork. This enables restorers to preview the results of different intervention strategies and arrive at the most feasible one. However, these algorithms require a large amount of training data and may not be entirely accurate in their interpretation of the artworks, necessitating discussions between art restorers and the artistic community. To prove the validity of these claims, the capabilities of such AI algorithms are evaluated in the next section.

Methodology

To review the current performance of AI in art restoration, we tested an AI Image Enhancer web application, VanceAI Photo Restorer, on images of three famous paintings. Powered by photo restoration technology, VanceAI instantly removes scratches from damaged photos, as well as tears, spots and dust. Besides that, VanceAI also possesses face enhancement and color restoration capabilities (VanceAI).

The three paintings tested were the Spanish “ecce homo”, the portrait of Princess Henrietta of England, and a painting of Saint Joseph. These paintings were chosen as they suffered from different forms of damage, ranging from flaked off components to severe tears. This would lead to a more comprehensive test of VanceAI’s capabilities. After images of the original paintings were fed to VanceAI, the author then benchmarked the reconstructed images against images of the actual restorations. The evaluation metrics used were the technical skill of repair, similarity to the original painting and the colors used in the restored painting.

Results and Discussion

Figure 3a. The original “ecce homo”

Figure 3b. The AI-generated restoration of “ecce homo”

Figure 3c. The human-restored “ecce homo”

The first painting tested was the Spanish “ecce homo”, with some of its components flaked off due to moisture. By inspecting the AI-restored image, the algorithm reduced some image blurs but failed to fill in all the flaked off components. Contrastingly, the human restorer filled in all the flaked off components but disrespected the original creation, disfiguring Jesus with a monkey-like appearance (Minder). Hence, the AI algorithm performed better in this case.

Figure 4a. The original portrait of Princess Henrietta of England

Figure 4b. The AI-generated restoration of Princess Henrietta's portrait

Figure 4c. The human-restored portrait of Princess Henrietta

Another painting tested was the 1665 portrait of Princess Henrietta of England, which was restored from old varnish and dirt (Bright Side). The AI algorithm significantly improved the clarity of the image, evident from the princess' sharper facial features and the creases in her gown.

The actual restoration also possesses sharper features, but has a less accurate color combination as duller shades were used. Hence, AI was arguably better in restoring this painting.

Figure 5a. The original Saint Joseph painting

Figure 5b. The AI-generated restoration of the Saint Joseph painting

Figure 5c. The human-restored painting of Saint Joseph

Last but not least, the AI algorithm was tested on a severely torn painting of St. Joseph (Fine Art Restoration Co.). The algorithm managed to close the cross tear, however traces of it (faint black lines) were still visible. Moreover, although more vibrant colors were used, the color contrast in the reconstructed painting looked artificial. On the other hand, its human-restored counterpart looked more complete without traces of the tear and the restorer followed the original painting's color scheme more closely. Thus, the human restorer outperformed the AI restorer.

Based on these experiments, today's AI algorithms are capable of performing as well, if not even better than human art restorers in proposing possible intervention methods for art restoration. However, there are still areas for improvement on restoring severe damages such as flaked off components and tears, and whether the AI's proposed changes are appropriate requires the combined evaluation of art restorers, art experts and historians.

Conclusion

In conclusion, AI currently plays the role of an assistant in the analysis stage of art restoration, accelerating the process, lowering costs and minimizing errors. However, as the evaluation of their digital reconstructions is subjective, current AI algorithms are still incapable of

aiding professionals in navigating the complex ethical boundaries that intersect their line of work. Nevertheless, by lessening the technical burden of art restorers, AI can enable art restorers to engage in more open discussions about the most appropriate treatment for each artwork which does not cross ethical boundaries. To further improve AI's success in art restoration, research can be done to minimize the amount of training data required, as well as to improve its performance on more severe artwork damages. Besides that, the artistic and scientific communities can together develop a benchmark for evaluating the digital reconstructions generated by these algorithms. In the near future, with AI in their toolkits, art restorers can successfully restore more damaged historical artworks to their former glory, uncover more stories of the past and gain a more complete narrative of our cultural heritage.

Works Cited

"16 Famous Paintings That Were Restored by Talented Professionals." *Bright Side*. 2020. https://brightside.me/articles/16-famous-paintings-that-were-restored-by-talented-professi onals-797948/. Accessed 15 Dec. 2023.

Aspuru, Ariana. "AI Digitally Restored a Lost Trio of Gustav Klimt Paintings. Not Everyone Is Happy About It." *Wall Street Journal*, 22 Oct. 2022, https://www.wsj.com/story/ai-digitally-restored-a-lost-trio-of-gustav-klimt-paintings-not everyone-is-happy-about-it-d75f54f8. Accessed 15 Dec. 2023.

Criddle, Christina. "Rembrandt's The Night Watch painting restored by AI." *BBC News*, 23 Jun. 2021, https://www.bbc.com/news/technology-57588270. Accessed 15 Dec. 2023.

"Favourite Restoration Projects of 2021." *Fine Art Restoration Co.*, 3 Dec. 2021, https://fineart-restoration.co.uk/news/favourite-restoration-projects-of-2021/. Accessed 15 Dec. 2023.

Learner, Thomas. "Modern and Contemporary Art: New Conservation Challenges, Conflicts, and Considerations." *Conservation Perspectives: The GCI Newsletter*, vol. 24, no. 2, 2009, pp. 5-9.

Minder, Raphael. "Despite Good Intentions, a Fresco in Spain Is Ruined." *The New York Times*, August 23, 2012. https://www.nytimes.com/2012/08/24/world/europe/botched-restoration-of-ecce-homo-fr esco-shocks-spain.html. Accessed 15 Dec. 2023.

"Old Photo Restoration Online with AI." *VanceAI*, 2023, https://vanceai.com/old-photo-restoration/. Accessed 15 Dec. 2023.

Scott, David. "Art Restoration and Its Contextualization." *The Journal of Aesthetic Education*, vol. 51, no. 2, 2017, pp. 82-104.

Van Saaze, Vivian. "Key Concepts and Developments in Conservation Theory and Practice." *Installation Art and the Museum: Presentation and Conservation of Changing Artworks*, 2013, pp. 35-60.