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学位論文題目	A Comprehensive Study of Image Inpainting for Addressing Conditional Missing Regions with Varied Feature Analysis. （多様な特徴分析を用いた条件付き欠損領域への画像修復）
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論文内容の要旨

Image inpainting assumes a fundamental role in the restoration of images with conditional missing regions, such as large-scale missing regions, regions with complicated structures and textures, foreshortened regions due to varying viewpoints, and high-resolution images generated from art paintings. This study aims to comprehensively explore various image inpainting methods, encompassing both traditional and deep learning-based approaches. While traditional methods, such as the fast marching method, diffusion inpainting, PatchMatch, and Image Melding, have demonstrated potential in addressing these conditional missing regions, they may introduce artifacts and encounter difficulties in accurately restoring them, thereby limiting their effectiveness in specific scenarios. Conversely, deep learning methods, including CNN-based approaches and GAN-based approaches, have emerged as promising alternatives, offering impressive inpainting results. However, these methods often require substantial computational resources, extended training time, and may suffer from long-term memory loss, resulting in blurred and unnatural restorations.

This study focuses on three primary problems in image inpainting. Firstly, we tackle the inpainting of regular and irregular missing regions in large-scale images. Our proposed method employs interactive structure propagation and color propagation methods to seamlessly integrate the missing regions with the surrounding content, ensuring visually coherent restorations. In the context of art paintings, which often feature intricate textures and structures created through brush strokes, we introduce a cohesive Laplacian fusion approach. This method preserves the intended artistic details and effectively restores both regular and irregular missing regions. Moreover, in planar spaces like the Manhattan World,

inpainting missing regions presents unique challenges due to varying viewpoints and the need to maintain spatial relationships. To overcome these challenges, we adopt orthogonal viewpoints and structure consistency methods, enabling accurate depth capture and ensuring visual coherence in the missing regions. Lastly, for high-resolution images where preserving fine details is crucial, we propose a multi-region Laplacian fusion approach that retains intricate details and enhances the overall quality of the restoration.

To evaluate the performance of our proposed method, we employ established perceptual quality metrics, including the Distortion-based Image Structural Similarity (DISTS), Learned Perceptual Image Patch Similarity (LPIPS), and other methods. Experimental results demonstrate that our method outperforms previous works in terms of perceptual quality. It successfully preserves the integrity of the restored images and generates visually pleasing inpainted results. Our approach effectively addresses the limitations of traditional methods, reducing artifacts in various missing regions, while also overcoming the issues of blurriness and unnatural restoration associated with deep learning methods. This reaffirms the effectiveness of our proposed method in image inpainting tasks.

論文審査の結果の要旨

画像インペインティングは，画像の補完に置いて重要な課題である．特に，大規模な損傷領域や複雑な構造やテクスチャを持つ損傷画像において，損傷領域の補完はまだ課題が残っている．本研究では，画像の損傷領域のサイズ，形状，及びテクスチャに焦点を当て，それぞれについて画像インペインティング方法を提案した．

画像の損傷領域のサイズや形状に関して，interactive structure propagation 及び color propoagation を基に，pixel-wise と patch-wise の特徴を用いた大規模な損傷領域を補完する画像インペインティングを提案した．さらに，3 次元から 2 次元に変換される画像の特徴を用いた画像インペインティング方法を提案した．テクスチャを含む損傷領域についても検討し，patch-wise と Laplacian fusion の特徴を用いて，画像インペインティング方法を提案した．最後に，multi-region Laplacian fusion の特徴を用いて，修復された画像に高解像度の処理を施した．

Structural Similarity Index Measure(SSIM)や，Feature Similarity Index Measure(FSIM)等の評価法を用いて，提案法の有効性を確認した．

これらの研究では，将来の美術品を画像としてデジタル化し，損傷領域を修復するために有用な知見が得られていると認められる．さらに，損傷領域のサイズ，形状，及びテクスチャに対して適切なアルゴリズムへの提案による得られた研究成果は美術品への修復に役立つと評価できる．

本学位論文は，いずれも申請者が著者に含まれる，レフェリー付きの学術雑誌論文 2 編及び国際会議プロシーディングス 5 編を元に作成された．その内の 4 編の論文で申請者が筆頭著者であ

る.

「学位論文の基礎となった論文」

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(3) **Structure-Texture Consistent Painting Completion for Artworks**, Irawati Nurmala Sari, and Weiwei Du, IEEE Access Journal, Vol. 11, Page(s): 27369-27381, March 2023.

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(6) **Image Inpainting using Automatic Structure Propagation with Auxiliary Line Construction,** Yuto Urano, Irawati Nurmala Sari, and Weiwei Du, The 23rd ACIS International Summer Virtual Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD-Summer), 6 pages, 2022.

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