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Feasibility Study of Inpainting and U-Net-Based MR Image Processing for Artifact Correction

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Background and objective: In MRI acquisition, magnetic susceptibility and motion artifacts frequently occur in patients with metallic implants, muscle disorders, and neurodegenerative diseases, as well as in pediatric and elderly populations, thereby hindering accurate image interpretation. Although recent studies have introduced deep learning and machine learning models for artifact correction and image restoration, a major challenge remains the scarcity of sufficiently effective training data. Therefore, we investigated the methodology and effectiveness of synthetic data based training datasets to overcome these limitations.

Methods: We conducted K-space–based experiments to generate two artifact types. For metallic (susceptibility) artifacts, we synthesized geometric distortion using a Bloch equation–based approach by embedding the spatial information of a metallic component within 3D volume data; an exemplar-based method was used in preprocessing. For motion artifacts, volumetric data were randomly rotated and translated in three dimensions with random magnitudes and repetition counts, and this procedure was repeated across all slices. For each slice, portions of motion-free K-space data were systematically substituted with motion-corrupted K-space data. We then reconstructed MR images containing artifacts and produced residual maps to construct datasets for training U-Net models. The similarity between real and synthesized artifact images was evaluated using Mutual Information (MI) and Fréchet Inception Distance (FID). Additional quantitative metrics included Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Coefficient of Variation (COV), and Contrast-to-Noise Ratio (CNR).

Results: For images synthesized with magnetic susceptibility and motion artifacts using the proposed method, MI increased and FID decreased compared with baseline approaches, indicating that the synthesized distortions shared more mutual information with the real distorted images. For metallic artifact reduction, SSIM improved by approximately 4.71% over the baseline. Relative to motion-corrupted inputs, RMSE was reduced by a factor of approximately 5.35 and PSNR increased by 1.51, approximately. Using a model trained with the proposed datasets, 35 real MRI containing susceptibility or motion artifacts were evaluated, demonstrating reduced distortion. In artifact-reduced images, CNR increased by approximately 1.4 compared with metallic-artifact images, and COV decreased by approximately 1.6 relative to motion-corrupted images.

Conclusions: The proposed synthetic data–driven training strategy effectively supports U-Net–based reduction of metallic and motion artifacts in MRI, demonstrating improved similarity to real distorted data and consistent gains in quantitative metrics.

Keywords: *Artifact correctio, Augmentation, Metallic implant, Patient motion, K-space*