A Generative Adversarial Network for Enhancing the Resolution of GPR B-scans

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Ground penetrating radar (GPR) is widely used to image the interiors of the structures such as tree trunks with internal defects, reinforced concrete columns, wooden utility poles, silos, and storage tanks. During the non-destructive testing or inspection of such structures, GPR is typically moved along a circular trajectory around these structures while emitting electromagnetic waves and receiving the reflected ones at each scanning point. The density of scanning points directly impacts the resolution of the GPR B-scans, with a large number of scanning points yielding high-resolution B-scans and images of the structures' interiors. That being said, performing a GPR survey on a large number of scanning points requires more accurate and reliable positioning systems to facilitate measurements (J. Qian, Y. H. Lee, K. Cheng, D. Qi, M. L. M. Yusof, D. Lee, and A. C. Yucel, "A Deep Learning-Augmented Stand-off Radar Scheme for Rapidly Detecting Tree Defects," *IEEE Trans. Geosci. Remote Sens.*, vol. 62, page 1-15, Jun. 2024), and increases the time for the data collection. To address this challenge, conventional interpolation methods have been applied to smooth and refine the features in B-scans (R. J. Oliveira, B. Caldeira, T. Teixido, J. F. Borges, and A. Carneiro, "Increasing the Lateral Resolution of 3D-GPR Datasets through 2D-FFT Interpolation with Application to a Case Study of the Roman Villa of Horta da Torre (Fronteira, Portugal),", *Remote Sens.*, vol. 14, issue 16, Aug. 2022). However, such methods often fail to capture subtle features related to reflections from internal defects or irregularities, limiting their effectiveness in resolution enhancement. Therefore, a more robust method is needed to improve the resolution of GPR B-scans.

In this study, we propose a generative adversarial network (GAN) (I. J. Goodfellow et al., "Generative Adversarial Nets," *Advances in Neural Information Processing Systems*, 27, 2014) to enhance the resolution of GPR B-scans. The proposed GAN effectively fills gaps between traces in low-resolution B-scans, generating high-resolution outputs enriched with both prominent and subtle features for reliable resolution enhancement. The GAN architecture consists of an encoder-decoder-based generator and a discriminator. The encoder extracts high-level features from sampling traces and analyzes correlations, while the decoder interprets this information to predict signals for the missing traces, thereby enhancing the B-scan resolution. The discriminator competes with the generator, driving it to produce high-resolution realistic images with high perceptual quality. This adversarial framework improves the network's generalization to unseen examples. Preliminary tests on synthetic B-scans of cylindrical objects demonstrate that the proposed GAN achieves a mean absolute error (MAE) of 0.51 and a structural similarity index measure (SSIM) of 0.81, outperforming conventional interpolation methods by 19.05% in MAE and 9.46% in SSIM. During the presentation, the GAN architecture will be explained in detail, its performance on real measurement data with varying numbers of scanning points will be discussed, and a comparison with other deep learning techniques will be provided.