S2M-Net: A Deep Learning-based Scheme for GPR Image Translation from Simulation to Measurement via a Conditional Generative Adversarial Network

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Ground-penetrating radar (GPR) has been widely used for the non-destructive inspection of subsurface structures in geophysical and civil engineering. To restore the subsurface information from the GPR data efficiently and accurately, deep learning-based methods have recently been investigated for GPR image classification, signature recognition, object detection, and structural image reconstruction (Z. Tong et al., *Constr. Build. Mater.*, 258, 120371, 2020.) (B. Liu et al., IEEE Trans. Geosci. and Remote Sens., 59(10), 8305-8325, 2021). To form a precise mapping between the GPR data and subsurface information via a deep learning model, large labeled GPR data sets are required for training and testing a deep neural network. Nevertheless, it is challenging to collect massive GPR data in the real world, as the repetitive measurements require excessive time, resources, and labor. On the other hand, the training and testing of the deep learning algorithms with the synthetic data obtained via simulations are often misleading due to the significant differences between synthetic and measurement data. To address these issues, a generative adversarial network (GAN) has recently been employed to generate GPR B-scans following the distribution of real ones from random noise (Q. Hui et al., *Autom. Constr.*, 130, 103830, 2021.). However, specific subsurface scenarios corresponding to the generated B-scans remain unknown, which results in challenges for creating a labeled dataset for training deep learning-based image restoration algorithms.

In this study, a deep learning scheme, called S2M-Net, is proposed for translating synthetic GPR B-scans with known subsurface scenarios into the measured ones. In particular, a conditional GAN (P. Isola et al., *IEEE Conf. Comput. Vis. Pattern Recognit.*, 1125-1134, 2017) is used to obtain measured B-scans corresponding to the provided synthetic B-scans obtained by simulations. The network architecture consists of a generator and a discriminator. The generator adopts a U-shaped encoder-decoder network (R. Olaf et al., *Int. Conf. Med. Image Comp. Comp Ass. Interv.*, 234-241, 2015) to generate measured B-scans from the given synthetic B-scans, while the discriminator employs a fully convolutional classifier to judge the authenticity of the generated B-scan. To train and test the proposed network, a set of data pairs are produced, including the synthetic B-scans obtained using an open-source time-domain simulator and the corresponding real measured B-scans with a commercial GPR system in an outdoor sandy field. Adversarial learning with the mean square error loss of the generator and the binary cross-entropy loss of the discriminator is conducted to optimize the network. The test results verify the capability of the proposed S2M-Net in the accurate and efficient generation of measured B-scans corresponding to given simulated B-scans. The mean relative error and structural similarity on the testing data are 5.8283% and 0.9457, respectively. These results demonstrate that the proposed network allows accurate mapping from synthetic B-scans with known subsurface scenarios to the corresponding measured B-scans. The comparison between the measured B-scans obtained by the proposed S2M-Net and the real measurements will be presented in the talk.