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Predicting Subsurface Abnormalities Growth Using Physics-Informed Neural Networks

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Abstract : The research explores the pioneering integration of Physics-Informed Neural Networks (PINNs) into the domain of Ground-Penetrating Radar (GPR) data prediction, akin to advancements in medical imaging for tracking tumor progression in the human body. This research presents a detailed development framework for a specialized PINN model proficient at interpreting and forecasting GPR data, much like how medical imaging models predict tumor behavior. By harnessing the synergy between deep learning algorithms and the physical laws governing subsurface structures—or, in medical terms, human tissues—the model effectively embeds the physics of electromagnetic wave propagation into its architecture. This ensures that predictions not only align with fundamental physical principles but also mirror the precision needed in medical diagnostics for detecting and monitoring tumors. The suggested deep learning structure comprises three components: a CNN, a spatial feature channel attention (SFCA) mechanism, and ConvLSTM, along with temporal feature frame attention (TFFA) modules. The attention mechanism computes channel attention and temporal attention weights using self-adaptation, thereby fine-tuning the visual and temporal feature responses to extract the most pertinent and significant visual and temporal features. By integrating physics directly into the neural network, our model has shown enhanced accuracy in forecasting GPR data. This improvement is vital for conducting effective assessments of bridge deck conditions and other evaluations related to civil infrastructure. The use of Physics-Informed Neural Networks (PINNs) has demonstrated the potential to transform the field of Non-Destructive Evaluation (NDE) by enhancing the precision of infrastructure deterioration predictions. Moreover, it offers a deeper insight into the fundamental mechanisms of deterioration, viewed through the prism of physics-based models.

Keywords : physics-informed neural networks, deep learning, ground-penetrating radar (GPR), NDE, ConvLSTM, physics, data driven
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