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Cross hole GPR traveltime inversion using a fast and accurate neural network as a forward model

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Probabilistic formulated inverse problems can be solved using Monte Carlo based sampling methods. In principle both advanced prior information, such as based on geostatistics, and complex non-linear forward physical models can be considered. However, in practice these methods can be associated with huge computational costs that in practice limit their application. This is not least due to the computational requirements related to solving the forward problem, where the physical response of some earth model has to be evaluated. Here, it is suggested to replace a numerical complex evaluation of the forward problem, with a trained neural network that can be evaluated very fast. This will introduce a modeling error, that is quantified probabilistically such that it can be accounted for during inversion. This allows a very fast and efficient Monte Carlo sampling of the solution to an inverse problem.
We demonstrate the methodology for first arrival travel time inversion of cross hole ground-penetrating radar (GPR) data. An accurate forward model, based on 2D full-waveform modeling followed by automatic travel time picking, is replaced by a fast neural network. This provides a sampling algorithm three orders of magnitude faster than using the full forward model, and considerably faster, and more accurate, than commonly used approximate forward models. The methodology has the potential to dramatically change the complexity of the types of inverse problems that can be solved using non-linear Monte Carlo sampling techniques.