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Neural Networks with an Application to global crustal Structure.

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Nonlinear inverse problems usually have no analytical solution and may be solved by Monte Carlo methods. Monte Carlo methods provide a set of samples, representative of the a posteriori distribution of the model parameters. We show how neural networks can be trained on these samples to give a continuous approximation to the inverse relation in a compact and computationally efficient form. Whereas traditional Monte Carlo methods require a full inversion for every new measurement, a trained neural network performs an inversion for a new data measurement instantaneously and provides similar probabilistic information about the solution. This illustrates that when repeated inversions are required, the cost of forming subsequent solutions can be reduced significantly by using neural networks.

The samples we use for network training consist of noiseless synthetic Rayleigh and Love wave phase and group velocities and the corresponding 1-dimensional Earth models. The roles of input and output variables from the well-defined forward problem (i.e. computing phase an group velocities for a given Earth model using normal mode theory) are interchanged. We train a neural network on phase and/or group velocities as input vectors and the corresponding Moho depths as outputs. The trained networks approximate the probabilistic inverse mapping from phase and group velocities to the consistent (posterior) Moho depth distribution. The posterior distribution of the model parameters might be multi-modal. For this reason we go beyond the single Gaussian description and model the posterior density distribution of the model parameters as a mixture of Gaussians. Controlling the complexity of the neural network mapping is crucial. We decide to add Gaussian noise to the synthetic phase and group velocities where the standard deviation of the noise is given by the measurement error of the real

phase and group velocities. Through the addition of the noise the network output is constrained to be less sensitive to small variations in the input variables.

The trained networks are applied to real data. The real data set consists of fundamental mode Love and Rayleigh phase and group velocity curves. For each inversion we obtain the probability distribution of Moho depth at a certain location. From this distribution any desired statistic such as mean and variance can be computed. We construct global maps of maximum likelihood crustal thickness with error bars attached to it. The obtained results are compared with current knowledge of crustal structure as in Crust2.0. Generally our results are in good agreement with Crust2.0. However we locate certain regions such as central Africa and the back arc of the Rocky Mountains where the Crust seems to be thinner than predicted by Crust2.0. In this application, characterized by repeated inversion of similar data the neural network approach proves to be very efficient. In particular, the speed of the individual inversions and the possibility of modeling the whole posterior distribution of the model parameters make neural networks a promising tool in seismic tomography.