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Fast, nonlinear, probabilistic inversion of large Geophysical problems

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Almost all Geophysical inverse problems are in reality nonlinear. Fully nonlinear inversion including non-approximated physics, and solving for probability distribution functions (pdf's) that describe the solution uncertainty, generally requires sampling-based Monte-Carlo style methods that are computationally intractable in most large problems. In order to solve such problems, physical relationships are usually linearized leading to efficiently-solved, (possibly iterated) linear inverse problems. However, it is well known that linearization can lead to erroneous solutions, and in particular to overly optimistic uncertainty estimates. What is needed across many Geophysical disciplines is a method to invert large inverse problems (or potentially tens of thousands of small inverse problems) fully probabilistically and without linearization.

This talk shows how very large nonlinear inverse problems can be solved fully probabilistically and incorporating any available prior information using mixture density networks (driven by neural network banks), provided the problem can be decomposed into many small inverse problems. In this talk I will explain the methodology, compare multi-dimensional pdf inversion results to full Monte Carlo solutions, and illustrate the method with two applications: first, inverting surface wave group and phase velocities for a fully-probabilistic global tomography model of the Earth's crust and mantle, and second inverting industrial 3D seismic data for petrophysical properties throughout and around a subsurface hydrocarbon reservoir. The latter problem is typically decomposed into 1000 to 1000000000 individual inverse problems, each solved fully probabilistically and without linearization. The results in both cases are sufficiently close to the Monte Carlo solution to exhibit realistic uncertainty, multimodality and bias. This provides far greater confidence in the results, and in decisions made on their basis.