Modeling Fluid Flows with Generative Neural Networks: Applications in Solid Earth Imaging

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Abstract

The resolution of inverse problems in physical sciences often requires exploring a large set of possible models and testing them against observed data. In fluid dynamics, this can be challenging, as running multiple flow simulations is often computationally prohibitive.

In this work, we propose training a neural network to replicate flow simulations (Figure 1). The trained network is then used to sample the set of flow models that explain the observed data. We apply this approach to adjust small-scale geological models of the upper mantle, characterized by marble cake textures, to smoothed tomographic data obtained from seismology. Our results demonstrate that the generated images are statistically consistent with theoretical models of mantle flow predicted from geodynamics.

Cast in a Bayesian framework, this approach enables us to address a highly nonlinear and non-unique inverse problem, where the solution is a probability distribution of possible mantle flow models that explain the noisy data observed at the surface of the Earth.

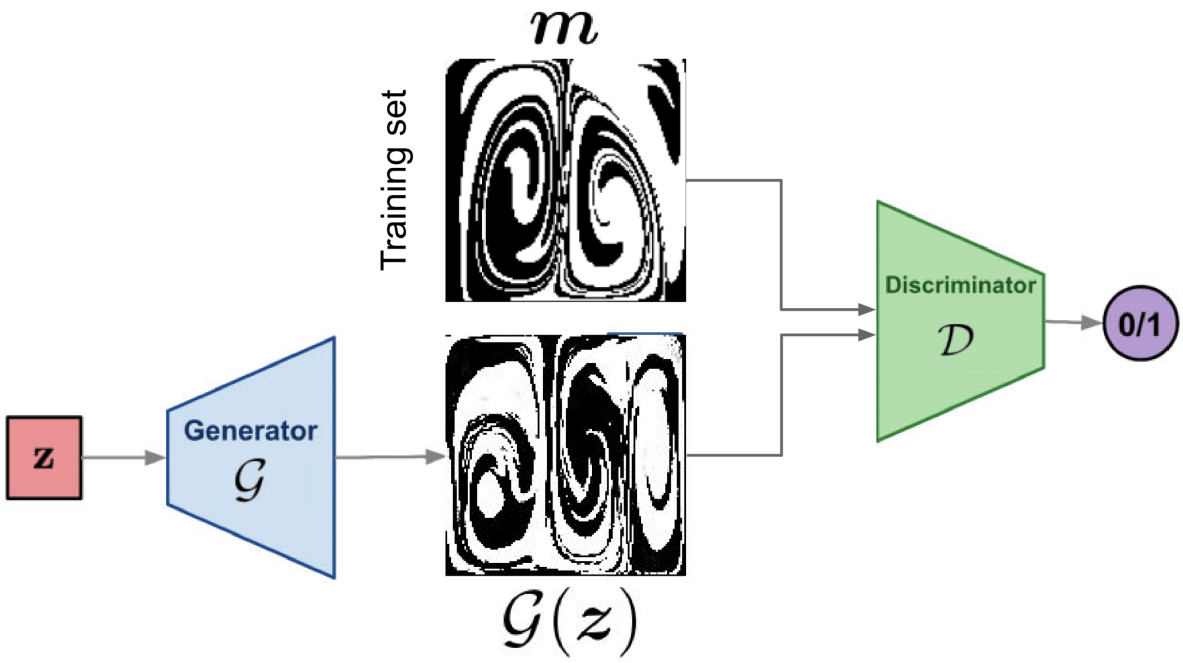

Figure 1: architecture of a Generative neural network designed to learn to generate random marble cake structures.

References

[1] T Santos, T Bodin, F Soulez, Y Ricard, Y Capdeville *Refining tomography with generative neural networks trained from geodynamics*, Geophys. J. Int. (2024) 238, 1676–1695.