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Differentiable Geomodelling: Towards Geomodel Insight and Task-Oriented Sensitivity Analysis

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Structural geological models are widely used for the prediction of geological structures and properties in science and engineering tasks. These predictions are often related to specific questions, for example the reservoir depth at a target location, unit thickness along a planned well trajectory, or distance-to-fault for safe subsurface storage. However, understanding which input parameters most strongly influence these task-specific quantities of interest (QoIs) remains challenging, particularly when models involve hundreds to thousands of input parameters.

In this contribution, we evalaute how automatic differentiation techniques, implemented in modern machine learning frameworks, can help.

While automatic differentiation and adjoint methods have become established tools in geophysical inversion and reservoir simulation, their systematic application to structural geological modeling with sensitivities to geometric features such as depth, thickness, or distance-to-fault remains limited. In this work, we introduce \emph{differentiable geomodelling} as a practical pathway to task-oriented sensitivity analysis. Building on implicit structural modelling concepts and the open-source geomodelling library GemPy, we formulate QoIs that remain differentiable with respect to geological inputs and compute local sensitivities via automatic differentiation using modern machine-learning frameworks (PyTorch).

The approach is tested in simplified settings and a realistic scenario with tens of input points and orientation measures. The results show that, rather than replacing global sensitivity analysis or uncertainty quantification, the proposed approach complements existing methods by providing an efficient screening and structuring tool for additional insight.