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Natural Environment Research Council

2023_29_ESE_Fang: Anisotropic geoelectrical imaging – can Artificial Intelligence (AI) replace conventional resistivity inversion approaches?

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We aim to develop a new interpretation workflow to account for electrical anisotropy in geoelectrical tomography in the most effective and computationally efficient manner. Such enhancements will be critical for emerging applications of geoelectrical imaging to reservoir characterisation and monitoring, in areas such as geothermal energy, underground gas/heat storage, or carbon capture & storage (CCS).

Modern geoelectrical imaging (e.g. electrical resistivity tomography, ERT) is routinely used to characterise the subsurface in 3D, and track subsurface processes over time (4D ERT, Wilkinson et al, 2022). Whilst nearly all studies assume electrically isotropic behaviour of the geological materials, in certain settings (e.g. finely bedded units with significantly varying properties) strong anisotropy is observed. This necessitates generalisation of tomographic methods to include anisotropic properties, if accurate images of the subsurface are to be obtained. ERT data affected by anisotropy can be interpreted with conventional (but appropriately modified) iterative resistivity inversion algorithms (e.g. Pain et al., 2003; Herwanger et al., 2004). However, this can present challenges due to computational demands and intrinsic ambiguities of traditional inverse modelling.

A promising alternative approach for diffusion-type problems such as geoelectrical imaging is to solve them directly using an Artificial Intelligence high fidelity model (AI-HFM). This can be done by calculating the weights/filters of convolutional layers using discretisation schemes. No training of the AI-HFM neural network is required for resolving the partial differential diffusion equation, as the weights are pre-determined and the result will be effectively the same as if the method was coded in a traditional way. The benefits of this approach are that (i) all infrastructure for efficient data assimilation is included, as all AI libraries have backpropagation functions, and (ii) using AI libraries for solving the PDEs allows easier inclusion of geology priors. The priors for the AI-HFM can be obtained by another NN trained to understand the geology using geological generator modelling results along with field measurements.

Our research will compare the two approaches to anisotropic tomography and will investigate their respective merits. The student will have access to rich and unique geoelectrical datasets exhibiting anisotropic behaviour, including 4D ERT cross-borehole monitoring data acquired at the UKGEOS Geoenergy Observatories (https://ukgeos.ac.uk/), a £31M programme being developed by the British Geological Survey for UKRI. The research will be led by the Applied Modelling & Computation Group at Imperial, and supervised by Dr Fang and Prof Pain. The ongoing development of geoelectrical methodology (instrumentation, theory, applications) undertaken at BGS (Wilkinson, Kuras) will provide underpinning context. Industry steer will come from Dr Herwanger, MP Geomechanics.