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Upscaling Microscale Flow Effects using Differentiable Programming

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Accurately predicting fluid flow through fractured media remains a major challenge due to the disparity between simple modeling assumptions and the complex reality of fracture geometry. Fractures at the continuum-scale are represented as very simple geometries, but in reality, fractures are quite complex. Assuming a parallel plate-like geometry in our numerical models can yield very high errors for fluid transport. While there have been numerous attempts to come up with a relationship that conveys micro-scale information about how fracture geometry influences flow at the continuum-scale, a universal equation remains elusive. This is partly due to the fact that effective properties used in these relationships fail to capture enough of the complexity of real fracture geometries. Machine learning approaches are promising, but integrating flow physics as hard-constraints in architectures has not been possible. Here, we introduce a novel application of differentiable programming in geosciences, enabling data-driven learning that adheres to fundamental conservation laws. This novel approach connects micro- and continuum-scale behavior, allowing us to come up with a general model for the permeability of rough, complex fractures. Our work paves the way for significantly improved flow predictions and ultimately a deeper understanding of multi-scale flow dynamics.

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References

Primary authors: MARCATO, Agnese (Los Alamos National Laboratory); O'MALLEY, Daniel; GUILTINAN, Eric (Los Alamos National Laboratory); VISWANATHAN, Hari (Los Alamos National Laboratory); Dr E. SANTOS, Javier (Los Alamos)

Presenter: MARCATO, Agnese (Los Alamos National Laboratory)

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