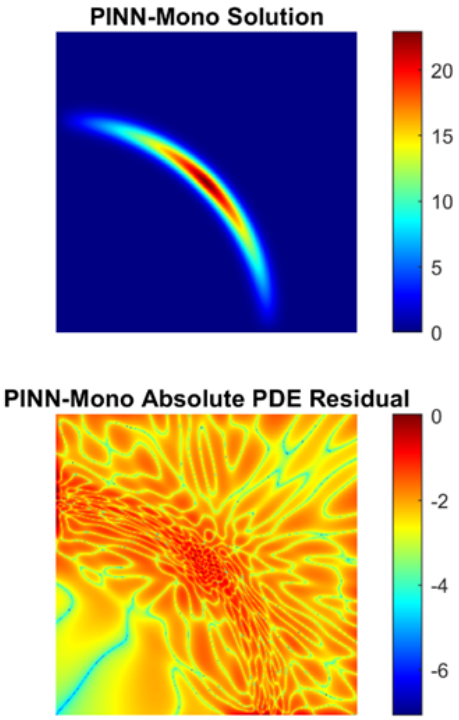
Discretization Methods for Anisotropic Diffusion Equations

This talk presents some recent advancements in finite volume discretization schemes, namely, nonlinear finite volume methods (NLFV) and how they compare to other consistent discretization schemes such as multipoint flux approximation (MPFA) and mimetic finite difference (MFD) in terms of monotonicity and positivity of solutions (maximum principle). Moreover, we explore the potential of physics informed neural networks (PINNs) in tackling systems with high anisotropic ratios to assess accuracy having removed gridding complications. A new loss function in physics informed neural networks is constructed to address monotonicity issues when solving highly anisotropic diffusion equations. The idea is to incorporate additional terms which penalize negative solutions in addition to the normal partial differential equation (PDE) residuals and boundary mismatch. Our results show that the new PINN models can accurately capture the tensorial effect of the diffusion tensor, and that by utilizing the new loss function we can reduce the degree of violations of monotonicity and improve the accuracy of solutions compared to the vanilla PINN models while the computational expenses remain comparable. We have also developed PINN models that are composed of multiple neural networks to deal with discontinuous diffusion tensors. Pressure and flux continuity conditions on the discontinuity line are used to stitch the multiple networks into a single model by adding another loss term in the loss function. The results demonstrate that the PINN models represent an attractive option for solving difficult anisotropic diffusion problems compared to traditional numerical discretization methods.



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Dr. Mohammed Al Kobaisi is an Associate Professor in the Petroleum Engineering Department at Khalifa University of Science and Technology (KU). In 2015 and 2016, Dr. Al Kobaisi was the Energy Affairs Manager in the Directorate of Energy and Climate Change (DECC) at the UAE Ministry of Foreign Affairs (MOFA) where he was in charge of the work on bilateral energy relations in oil, gas, and renewable energy. Moreover, he was the Deputy Permanent Representative of the UAE Mission to the International Renewable Energy Agency (IRENA) and an Advisor to the Ministry of Climate Change and Environment (MOCCAE) in 2017. In 2011 and 2012, Dr. Al Kobaisi was a Visiting Assistant Professor at Stanford University.

His scientific contributions revolve around the numerical modeling of fluid flow and transport in natural porous media. He is primarily focused on the efficient and accurate performance prediction of large scale (full field), highly heterogeneous reservoirs. Specific interests include multiscale simulation, gridding and upscaling techniques, pressure-transient analysis (analytical and numerical), computational physics of multiphase flow and storage, advanced discretization schemes, and fast computational algorithms. Dr. Al Kobaisi holds BSc, MSc, and PhD degrees in Petroleum Engineering from the Colorado School of Mines. He is a member of the Society of Petroleum Engineers (SPE), the Society for Industrial and Applied Mathematics (SIAM), and the European Association of Geoscientists and Engineers (EAGE).

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