# Real-time-scale hydraulic fracture monitoring using an extended Kalman filter-reduced model

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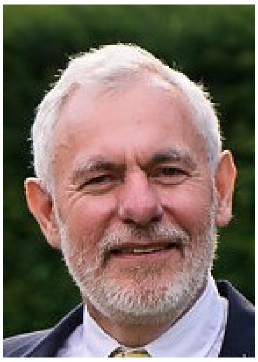

Anthony Peirce is a Professor in the Department of Mathematics at the University of British Columbia, Canada. His presentation will be at 9:00 Central Time on Thursday, August 6, 2026. The topic is **"Real-time-scale hydraulic fracture monitoring using an extended Kalman filter-reduced model."**

## Abstract

Inverting remote tiltmeter data to locate evolving hydraulic fracture footprints is a classically ill-posed problem due to the fact that the elliptic PDE that governs the behaviour of the displacement gradient field rapidly smooths the geometric details of the fracture with distance. Indeed, it is possible to show that it is only feasible to obtain reasonable estimates of the first few moments of the crack opening displacement field from such measurements. However, by combining the remote tiltmeter data with a dynamic hydraulic fracture (HF) model it is possible to use the titlmeter data to update the dynamics of the HF model in a way that incorporates significant physical processes that have not been included in the original HF model. This has been achieved by combining the extended Kalman Filter (EKF) with an Implicit Level Set Algorithm (ILSA) to provide maximum likelihood estimates of the state variables that characterize the evolving HF. The ILSA-EKF algorithm has been applied to monitor the progress of preconditioning in mining operations, and to monitor the creation of hydraulic fractures for energy storage. However, the ILSA-EKF algorithm is computationally intensive and only suitable for post-processing of tiltmeter data. The EKF has recently been combined with a reduced order model (EKF-R) to achieve real-time-scale imaging of hydraulic fracture footprints.

In this talk I will give a brief introduction to the tiltmeter inversion problem, the Extended Kalman Filter, and the ILSA and reduced order

hydraulic fracture models. The computational efficiency of the reduced order model results from limiting the number of degrees of freedom required to define the state of the hydraulic fracture to five - compared the order of magnitude (or more) degrees of freedom required for the fully planar ILSA model. Given the considerable uncertainties in both material properties of the elastic medium and the prevailing stress conditions in the field, a detailed fully planar model might not warrant the additional computational expense. Indeed, the EKF is able to compensate for considerable un-modelled dynamics while the reduced model offers sufficient computational efficiency to make real-time monitoring a possibility. In this talk I will demonstrate the efficacy of the EKF-R algorithm and explore its sensitivity to uncertainties in the material properties in the solid medium, the confining stress field, and the geometric distribution of tiltmeters. The ILSA-EKF model requires a priori knowledge of the fracture plane orientation. In this talk I will also demonstrate how the EKF-R algorithm can be adapted to rapidly determine the fracture orientation early in evolution of the fracture by minimizing the difference between the measured tilt vectors and those that correspond to the EKF-R solution. A practical field implementation of such a real-time-scale imaging would open the potential for real-time monitoring and even possible control of the dynamics of the hydraulic fracture.

## Biography

Anthony Peirce is a Professor in the Department of Mathematics at the University of British Columbia, Canada. During his PhD work as a Fulbright Scholar at Princeton University, he pioneered work on the optimal control of quantum molecular systems. Prior to his PhD, he worked as an applied mathematician at the Chamber of Mines Research Laboratories in South Africa, where he investigated rock fracture processes. His research contributions in hydraulic fracture modeling, along with collaborators, include the development of: the Implicit Level Set Algorithm (ILSA), which enables the use of multiscale tip asymptotics to accurately represent the fracture width on a coarse mesh and locate the fracture free boundary; the EKF-ILSA code, which uses tiltmeter measurements to monitor the growth of hydraulic fractures in mines; a proppant model able to capture Poiseuille to Darcy flow and proppant packing; and an accurate technique to capture multiple elastic layers in the Planar3D Simulator using the Fourier Transform. He has published extensively on his research and has two US Patents. Further details are available on his website: www.math.ubc.ca/~peirce.