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Anisotropic diffusion-based smoothing filters for full-waveform inversion

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Smoothing filters are commonly used in full-waveform inversion to precondition the descent direction and to mitigate the ill-posedness of the inverse problem. However, conventional Gaussian filters typically require rectilinear meshes, which are incompatible with the unstructured meshes that modern spectral-element-based waveform simulators operate on, and therefore necessitate cumbersome projections between the different discretizations.

To mitigate this limitation, we propose a strategy based on the diffusion equation involving an anisotropic and space-dependent diffusion operator that includes spatially varying smoothing lengths, variable smoothing directions, and automatic detection of internal discontinuities and solid-fluid interfaces. The same spectral-element framework can be utilized to solve both wave and diffusion equations, which works matrix-free, fully explicit and avoids the need of solving a large-scale linear system. This results in a performant and highly scalable algorithm.

Furthermore, we extent the L-BFGS framework and design an inversion method that fully integrates the diffusion equation and regularization terms instead of applying the smoothing filter to the raw sensitivity kernels. This is a crucial step to obtain consistent search directions that avoids frequent restarts of the Hessian approximation and results in a faster convergence rate.

We demonstrate the capability and efficiency of the smoothing filter in several synthetic examples from local to global scale. Furthermore, we showcase its application in ongoing work of a full waveform inversion of the Australasian region.