Green's theorem framework for data reconstruction

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SUMMARY

There is a tremendous and pressing need to improve our ability to effectively extrapolate, interpolate and regularize seimic data. That drives the interest in methods of data reconstruction in general.

In the last decade, there has been an ever increasing attention to methods dealing with interferometry to reconstruct wavefield in new locations (limited to locations where sources or receivers exist). This attention has brought about a renewed interest in Green's theorem because all different approaches to interferometry can be derived from it. Interferometric techniques are approximations to Green's theorem. Interferometry in general uses two measure pressure wavefields and two high-frequency and one-way wave approximations to Green's theorem. The approximations are made because the exact formula derived from Green's theorem requires a second measurement --the normal derivative of the pressure field at the recording surface, hence, with the approximations only the pressure field is needed. If interferometry is used to reconstruct data in environments where strong two-way waves exist (such as in marine surface seismic experiments, where the free-surface reflects all the upgoing energy as strong downgoing energy) errors and artifacts are produced in the synthesized wavefield due to the approximations. There are different ways to deal with these artifacts (also known as spurious multiples), for example, Dong and Schuster (2008) use shaping filters and iterations to reduce the effect of the artifacts in the reconstructed data (see also the UTAM 2008 annual report).

In this presentation, a different approach is used: The approach starts with Green's theorem, and instead of using directly the approximations made by interferometry, we use different auxiliary functions to obtain methods for data reconstruction with different degrees of approximations and effectiveness, including methods with no approximations. For example, direct wave interferometry uses the measure pressure data, a reference (constant velocity) Green's function and a single approximation, and shows added value in the reconstructed wavefield (see attached paper). We also provide two algorithms for data reconstruction purely based on Green's theorem with no approximations. The first one requires dual measurements (pressure field and its normal derivative at the measurement surface) and uses a reference Green's function. The second one requires only a single measurement (pressure field) and uses a double-Dirichlet Green's function (vanishing at the free-surface and at the measurement surface). These three techniques allow reconstructing the wavefield anywhere between the measurement surface and the free surface. The three techniques deal and use the fact that two-way waves exist when dealing with measurements close to the free-surface. Numerical examples and comparisons will be shown.

For this presentation the theory, examples, comparisons and conclusions are limited to measurements within the water column in a marine experiment with controlled sources.