A proposal for model-independent 3D wave field reconstruction from reflection data

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Inspiration for this work:

Connection of scattering principles: a visual and mathematical tour: CWP paper

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Connection of scattering principles: focusing the wavefield without source or receiver

Today, 2:45 PM, This Room (218)
Can we retrieve a virtual-source response, including all internal multiples, from surface measurements only?
Contents

• Thought experiment
• Iterative scheme for wave-field reconstruction
• Conclusions
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Thought experiment

lossless medium
Thought experiment
Thought experiment
Thought experiment
Thought experiment
Thought experiment

Assumption: between red curves $D(x, 0, t) = -U(x, 0, -t)$
Thought experiment

Superposition:

\[ D(x, 0, t) + U(x, 0, t) \]

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Superposition:

\[ D(x, 0, t) + U(x, 0, t) \]

Add time-reversed field:

\[ D(x, 0, t) + U(x, 0, t) + D(x, 0, -t) + U(x, 0, -t) \]

Assumption: between red curves

\[ D(x, 0, t) = -U(x, 0, -t) \]
Thought experiment

Superposition:

\[ D(x, 0, t) + U(x, 0, t) \]

Add time-reversed field:

\[ \overline{D(x, 0, t)} + U(x, 0, t) + \overline{D(x, 0, -t)} + \overline{U(x, 0, -t)} \]

Assumption: between red curves \[ D(x, 0, t) = -U(x, 0, -t) \]
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Thought experiment

Superposition:

\[ D(x, 0, t) + U(x, 0, t) \]

Add time-reversed field:

\[
\overline{D(x, 0, t)} + \overline{U(x, 0, t)} + \\
\overline{D(x, 0, -t)} + \overline{U(x, 0, -t)}
\]

\[ = 0 \quad \text{between red curves} \]

Assumption: between red curves \[ D(x, 0, t) = -U(x, 0, -t) \]
Thought experiment
Thought experiment
Thought experiment

Superposition
Thought experiment

Add time-reversed field
Thought experiment

Add time-reversed field
Thought experiment

First arrival: primary response of virtual source
Thought experiment

First arrival: primary response of virtual source

Total field: solution of wave equation
Thought experiment

First arrival: primary response of virtual source

Total field: solution of wave equation

Causal part: upgoing at z=0
Thought experiment
Conclusion of thought experiment is plausible, but do we really get the full virtual-source response?
Conclusion of thought experiment is plausible, but do we really get the full virtual-source response?

How do we achieve that

\[ D(x, 0, t) = -U(x, 0, -t) \]

between red curves?
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Convolve with reflection response and sum over all sources.
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Convolve with reflection response and sum over all sources.
Superposition

downgoing

downgoing + upgoing

upgoing
Superposition

Add time-reversed field
Take causal part
Directly modeled response
Summary:
Measured reflection response at surface, plus estimate of primary virtual source response, gives full virtual-source response.
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‘Model-independent’ wave-field reconstruction requires:
• Reflection data at the surface
• Estimate of primary traveltimes
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Consequences:
• Virtual-source response, including internal multiples
• Basis for imaging, accounting for internal multiples
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To be investigated:
• Mathematical model
• Limitations, due to finite acquisition aperture, triplications, errors in traveltimes, head waves, fine-layering, etc.
• Elastodynamic extension
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