Generalized Waveform Inverse

An Accelerated Approach

Daniel Abel[1] Michiel de Reus [1]

[1]Alten Nederland

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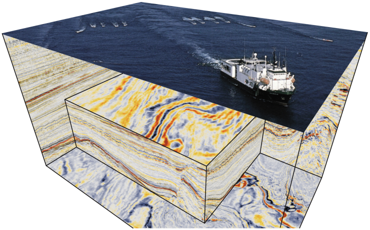
Contents

Applications

- seismology
- weld testing
- non-destructive testing - ground radar
- medical: ultrasonic applications

and possibly

- radar
- sonar
- Röntgen (attenuation $\rightarrow$ Radon)



Waves

What do these application have in common? They all use waves!

Calculational Challenge

Limitations:

- memory requirement
- calculational effort necessary

currently computers are getting big and fast enough and companies are starting to explore waveform inversion!

Business Perspective

- faster and more efficient calculations
  - saves expenses
  - higher returns, more gain
- better results yields effectivity and makes business more profitable
- automatic assessments means big savings in time and resources

Why Alten?

- active in many areas with broader perspective and interest than any single specialized company
- strong and established scientific software engineering group
- hands-on capabilities to realize the actual algorithm and product

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Alten Perspective

- starting point for contact and discussion with (new) businesses
- demonstration of capabilities and independence
- prestige and image
- attracting new scientific engineering talent

Possible Targets

- application for
  - seismology
  - weld inspection
  - ultrasonic
- demonstration for job fair or client - information sessions
- examples of real data / synthetic data
- publication of review and results

First: acoustic domain decomposition on gpu
and velocity c field inversion
or velocity and density fields c, ρ inversion

Challenges

There are three kind of challenges which need to be met

- Theoretical - find a framework that describes and combines the equations of different systems
- Numerical - find an approach that works well on the gpu and speeds up the calculation with minimum amount of resources
- Technical - implement the algorithm on the gpu

Challenges - Theoretical

- solve the acoustic equations
- solve the elastic equations
- describe and solve different properties
  - stiffness κ and density ρ
  - Lamé parameters, λ and μ, and density ρ for solids
- take into account dissipation (optional)
- glue together regions with different media

Challenges - Numerical Theory

- work out algorithmically and numerically accelerated approach using domains
- describe surfaces separating different media or discontinuous properties

Challenges - Technical

- make CUDA-c implementation
- ...

Theory - Acoustic Integral Equation

Acoustic equation for velocity and density field:

$$p(\mathbf{r}) = p_0(\mathbf{r}) - \omega^2 \int_V \frac{1}{\kappa_0} \chi_\kappa p(\mathbf{r}') \; G^{(0)}(\mathbf{r}', \mathbf{r}) \,\mathrm{d}V' + \int_V \frac{1}{\rho_0} \chi_\rho \boldsymbol{\nabla} G^{(0)}(\mathbf{r}', \mathbf{r}) \cdot \boldsymbol{\nabla} p(\mathbf{r}') \,\mathrm{d}V'$$

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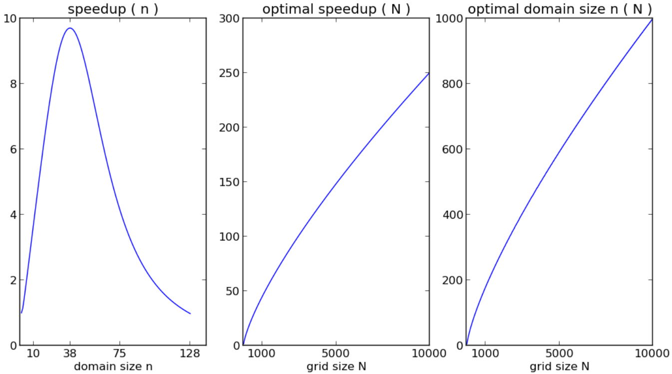
Theory - Acoustic Integral Equation For Domain

Boundary term representing outside influence on domain

$$
\begin{aligned}
p(\mathbf{r}) = &-\omega^2 \int_V \frac{1}{\kappa_0} \chi_\kappa p(\mathbf{r}')\; G^{(0)}(\mathbf{r}', \mathbf{r})\, \mathrm{d}V' \\
&+ \int_V \frac{1}{\rho_0} \chi_\rho \boldsymbol{\nabla} G^{(0)}(\mathbf{r}', \mathbf{r}) \cdot \boldsymbol{\nabla} p(\mathbf{r}')\, \mathrm{d}V' \\
&- \oint_S \left(\frac{1}{\rho_0} p(\mathbf{r}') \boldsymbol{\nabla} G^{(0)}(\mathbf{r}', \mathbf{r}) - \frac{1}{\rho} G^{(0)}(\mathbf{r}', \mathbf{r}) \boldsymbol{\nabla} p(\mathbf{r}') \right) \cdot \hat{\mathbf{n}}\, \mathrm{d}S'
\end{aligned}
$$

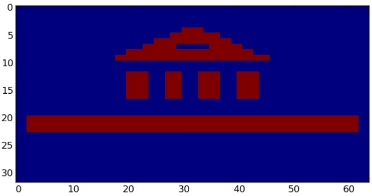
Algorithmic Speedup Domain Decomposition



Demo

Inverting the media properties of a synthetic model

real model



inverted model