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From Elastic Wave Simulation to Ultrasonic Wavefield Imaging and Inversion

Luan T. Nguyen & Erik H. Saenger
International Geothermal Centre, Bochum University of Applied Sciences, Germany

1. Elastic Wave Simulation

Elastic wave equation

$$\rho \partial_t^2 u = \nabla \cdot \sigma + f$$

$$\sigma = 2\mu\varepsilon + \lambda \mathrm{tr}(\varepsilon)\delta \quad \text{(isotropic material)}$$

$$\sigma \cdot \hat{n} = 0 \quad \text{(traction-free boundaries)}$$

Forward and adjoint wavefields

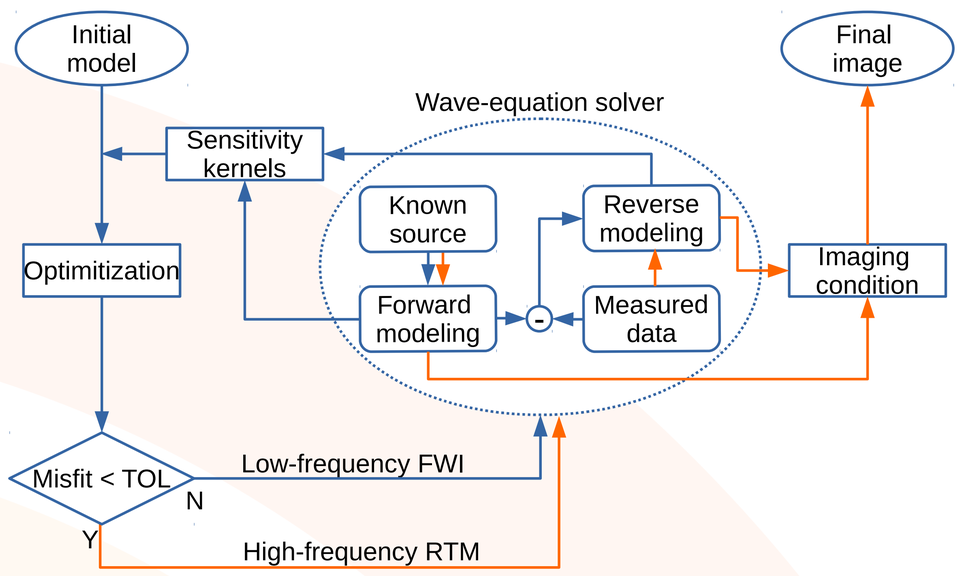
$$s(x,t) = \int G(x, x_s, t-t') f(t') dt'$$

$$s^\dagger(x,t) = \int G(x, x_r, t-t')[s(x_r,t') - d(t')] dt'$$

The elastic wave equation can be effectively solved by the rotated staggered grid finite difference method (Saenger et al. 2000) and the spectral element package SPECFEM3D (Komatitsch & Tromp 1999). Both programs scale on a computer cluster.

2. Full Wavefield Imaging Workflow

A combined ultrasonic imaging workflow (Nguyen & Modrak 2018)



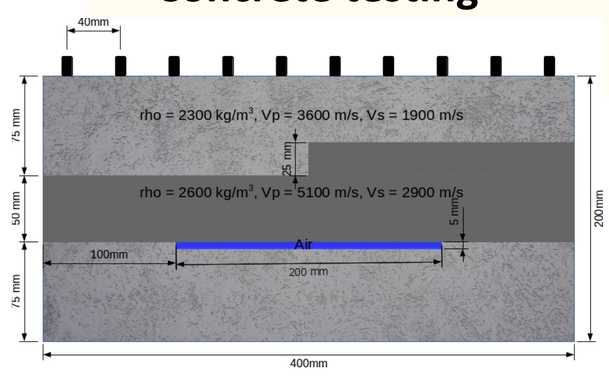
Advantages:

- Large-scale background velocity model is built by low-frequency full waveform inversion (FWI).
- Small-scale defects are imaged by high-frequency reverse time migration (RTM).
- Imaging workflow management takes advantages of parralelization over MPI domains and shots.

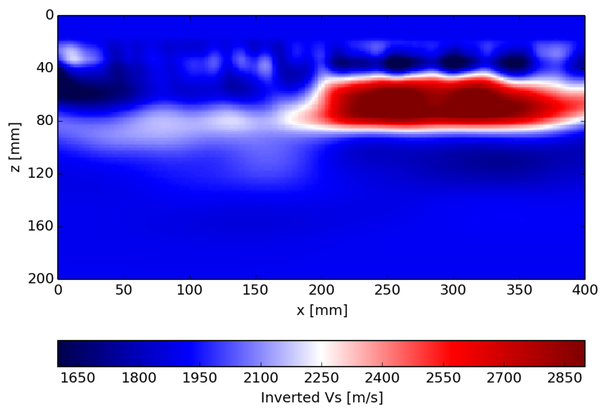
3. Nondestructive testing applications

Concrete testing

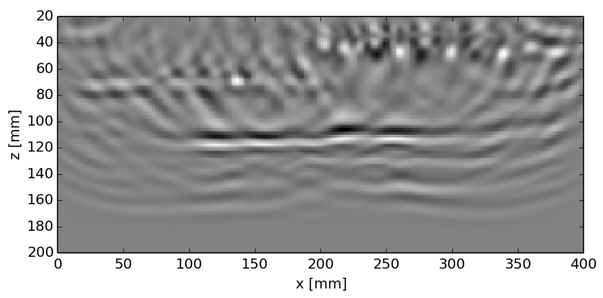
Test case



40 kHz FWI

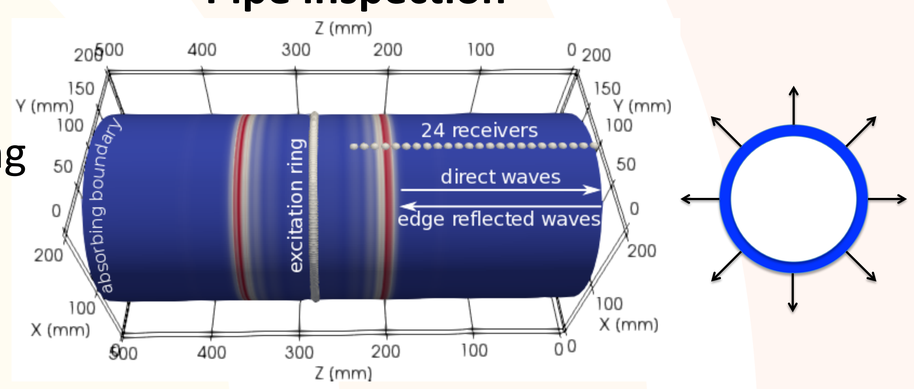


100 kHz RTM

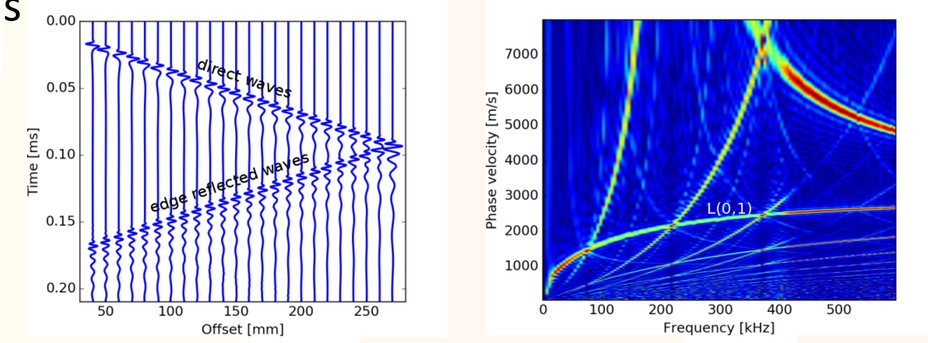


Pipe inspection

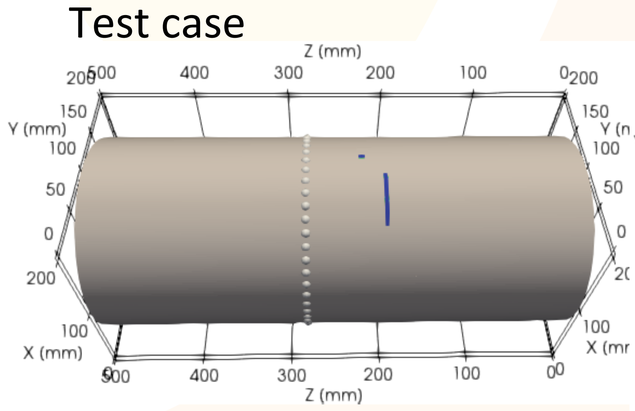
3D modeling



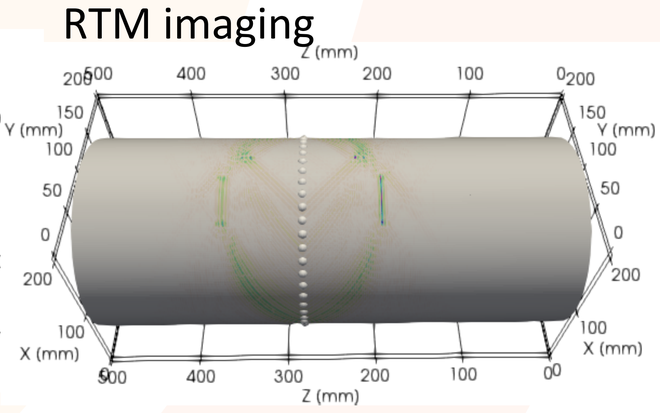
Dispersion analysis



Test case



RTM imaging



Acknowledgement We gratefully acknowledge the computing time granted by the John von Neumann Institute for Computing (NIC) and provided on the supercomputer JURECA at Forschungszentrum Jülich.

References

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