Back and Through the Looking Glass-Space-time scattering of elastic waves

Author(s):
Aichele, Johannes; Müller, Jonas; Nissar, Zabreen; van Manen, Dirk-Jan; Serra-Garcia, Marc

Publication date:
2023-04-27

Permanent link:
https://doi.org/10.3929/ethz-b-000653793

Originally published in:
EGUsphere, https://doi.org/10.5194/egusphere-egu23-13540

EGU23-13540, updated on 21 Feb 2024
https://doi.org/10.5194/egusphere-egu23-13540
EGU General Assembly 2023

Back and Through the Looking Glass - Space-time scattering of elastic waves

Johannes Aichele[1], Jonas Müller[1], Zabreen Nissar[2], Dirk-Jan van Manen[1], and Marc Serra-Garcia[2]
[1]ETH Zurich, Institute of Geophysics, Zurich, Switzerland (johannes.aichele@rwth-aachen.de)
[2]AMOLF, Amsterdam, The Netherlands

Due to causality wave scattering in time is simpler than scattering in space: In contrast to multiple spatial boundaries, there are no infinite reflections between temporal boundaries. Salem and Caloz, 2015 [1] showed that wave scattering can be simplified by constructing a time-space cross-mapping. We identify the cross-mapped wavefields as the Focusing functions developed in data-driven geophysical imaging. Experimentally, Bacot et al, 2016 [2] have shown that time modulation of the medium properties of a capillary-gravity wave results in time-refraction and time-reflection of the original wave. This experimental result should hold true for any system obeying Alembert's equation. This should in principle allow us to physically compute wavefields for the single-sided inverse scattering problem through forward scattering experiments. We set up a simple comb-like discrete system for time-modulated 1D elastic wave propagation. Elastic beams act as the masses and an electrostatic force as the springs of our system. The effective coupling stiffness between the beams is modulated in time through a variation of the electrostatic force. A Galerkin based wave propagation model shows that an experimental realization of hundreds of beams can be achieved through micro-machining. Through time-modulations of the system's wavespeed a broadband excitation is refracted and reflected everywhere in space. Time-scattering preserves the wave vector k, which implies that the frequency ω is not conserved. To elucidate the dispersion relation at time boundaries, we employ a correction method for spatial dispersion. Herefore, a correction method for time-dispersion in finite difference simulations developed by Koene et al 2018 [3] is mapped to the spatial dimension of our meta-material.
[1] Salem, Mohamed A., and Christophe Caloz. "Space-Time Cross-Mapping and Application to Wave Scattering." ArXiv:1504.02012 [Physics], April 7, 2015. http://arxiv.org/abs/1504.02012. [2] Bacot, Vincent, Matthieu Labousse, Antonin Eddi, Mathias Fink, and Emmanuel Fort. "Time Reversal and Holography with Spacetime Transformations." Nature Physics 12, no. 10 (October 2016): 972–77. https://doi.org/10.1038/nphys3810. [3] Koene, Erik F M, Johan O A

Robertsson, Filippo Broggini, and Fredrik Andersson. “Eliminating Time Dispersion from Seismic Wave Modeling.” Geophysical Journal International 213, no. 1 (April 1, 2018): 169–80. https://doi.org/10/gcz9wb.