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Forward and inverse modeling of seismic waves for reconnaissance in mechanized tunneling

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For tunnel excavation, it is important to predict the geological environment and the underlying geotechnical parameters, because the soil conditions are influencing the safety of the construction site, the speed of excavation, the wearing of tools and with supporting measurements, the surface settlements. To get information on the ground along the tunnel track, especially during construction, one can use seismic imaging. But interpreting the data can be difficult, because measurements are usually taken inside the tunnel.
For a deeper understanding of seismic wave propagation in a tunnel environment, numerical simulations using the Spectral Element Method (SEM) and the Nodal Discontinuous Galerkin Method (NDG) are used. The methods are based on the finite element method but are using high order polynomials to reconstruct the wave field inside the elements leading to high order elastodynamic simulations. The SEM is a fast and widely used method in the seismic community, but its biggest drawback is the limitation to hexahedral elements. For complex heterogeneous models with a tunnel included, it could be more convenient to use the NDG, which require more computation time but can be adapted to tetrahedral elements without the need to invert global matrices. Using the two techniques, high resolution massively parallel simulations of seismic waves initialized by a single force acting either on the front face or the side face of the tunnel are carried out. This produces waves that travel mainly in the direction of the tunnel track. The task is to get as much information as possible from the backscattered part of the wave field. For a 2D tunnel setting an inversion is calculated with the SEM and a non-linear conjugate gradient method. The adjoint kernels, which are the gradient of the misfit function between synthetic data and the numerical test model are used for this purpose. As a preliminary result, it is possible to image at least interfaces of scatterers in the model.