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Numerical Simulation of Complex Seismic Problems in Heterogeneous Media using High-Performance Computing Systems

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Numerical simulation of seismic processes in heterogeneous media has a numerous applications: oil and gas seismic survey process, global planet model creation and improvements, etc. This approach has a lot of advantages comparing with natural experiments: low cost, high precision and ability of changes medium structure arbitrarily.

In this work the new approach for modeling of seismic processes in complex heterogeneous (containing inclusions, cracks, holes, etc.) media is described. It is based on the solution of hyperbolic system of equations for elastic media. At the initial stage the structured curvilinear mesh is generated. All heterogeneous is depicted at this stage with their borders. For example, infinitesimal long crack has two sides and a set of nodes on both of them. Secondly, we solve equations numerically using grid-characteristic method. The main advantage of this method is the possibility of setting correct contact and border conditions combined with high precision of calculations. It is possible explicitly to model fluid and gas filled cracks without crucially mesh refinement. For this purpose special conditions are applied at all steps of calculations.

One of the drawbacks of direct solution of hyperbolic equations comparing with rough semi-analytical solution is the increasing time of computations. To eliminate this problem the research software was developed with realization of spatial approach for parallel computations. Using MPI technology at the initial step whole mesh is separated between all available processors\cores to load them equally. According to the empirical tests the scalability of parallel algorithms is about 80 % up to 16 000 cores at least.

A set of interesting practical results were obtained using proposed method. In the report the results of modeling seismic process (including intensive earthquake) in the Earth model will be shown. Ability of modeling fractured media allowed us to obtain seismic response from cluster of vertical fluid-filled geological cracks in full 3D case. The intensive of this response was compared with the case of gas-filled cracks.

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