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PARALLEL ALGORITHMS FOR PROBLEMS OF A MEDIUM STRUCTURE RECONSTRUCTION[1]

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Reconstruction of a medium structure is a problem of a great interest in many fields, such as geophysics, medicine, quantum mechanics, and non-destructive testing. In particular, being applied to the structure of lithosphere, it aids in assertion of inhomogeneities in Earth's crust and upper mantle and in determining a complex structure of lithospheric plates.

The problem under consideration consists in reconstruction of Earth structure from the data obtained along different wave paths. The values to be determined are seismic wave velocities, and the input data are travel times and coordinates of sources and receivers of seismic signal.

Surface waves propagate in upper layers of the Earth, and the thickness of the layer, in which the most part of their energy is concentrated, depends on the wavelength: the larger is the wavelength, the deeper the wave is penetrated. For small enough wavelength, the problem may be reduced to the inverse problem of ray seismics based on the data on surface wave observations.

A widely used technique for solving the inverse problem of seismics is the Backus—Gilbert approach. It permits to obtain a smooth velocity distribution function from a discrete set of data. According to this approach, lateral disturbances of slowness are taken as unknown values instead of the velocity distribution. By so doing, the initial non-linear problem is linearized and transformed to an optimization problem. The latter consists in minimization of a functional in a Hilbert space under constraints in form of linear inequalities. The amount of the inequalities is the double number of observed data. For solving this optimization problem, the constraint aggregation method is applied.

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The procedure suggested for solving the problem of ray seismics includes "outer iterations", each containing several "inner iterations". At every step of the outer cycle, the initial shape of seismic rays is computed from the velocity distribution found at the previous step. This is made by performing a ray tracing procedure (solving direct problem of seismics). A reasonable quality of computation can be achieved if the data set is large enough and the computation uses a detailed enough discretization of domain and rays. Under such conditions, the problem becomes unrealistic for personal computers.

When choosing the scheme of parallel computations, we took into account both diversification of time necessary for different parts of the algorithm and size of data needed for the computation. Ray tracing, which is performed between the outer iterations, turns out to be the most time consuming task, whereas the most memory is consumed by the inverse problem. In case of sequential realization of the algorithm, time fraction taken by the ray tracing is about 0.98. So, it makes sense to parallelize namely the procedure of solving direct problem within each outer iteration.

In order to optimize computation time and data exchange time we chose the model "master—workers". The master process is responsible for solving inverse problem (i. e. processing internal iterations), distributing rays over workers, collecting the results and producing the final output. Workers trace rays, find new travel times for each ray, form the input data for inverse problem and send them back to the master process.

One of the difficulties in elaboration the parallelization scheme is that the processor time spent for tracing a ray strongly depends on the ray's length, which is not known exactly. This leads to a non-uniform load of processors. To ensure that rays are evenly distributed amongst the processes, their lengths are estimated by distances between source and receiver.

A series of computational experiments was performed on a multiprocessor computer with i860 processors and distributed memory. In typical cases, a proper distribution of tasks over processes permits to reach the efficiency of computations of 0.75. A number close to 10 processors gives the most effective computation, although further increasing of the number of processors gives a significant acceleration.

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