



Accelerating of the reservoir simulation by the GPU

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Prior to CCS project, it is very important to evaluate the soundness of the injection site by simulating the behavior of carbon dioxide injected into the reservoir. Monte Carlo approach is often used for the statistical evaluation of reservoir because its models include much uncertainty. This approach requires a number of simulations and it is very time consuming. Therefore we accelerated the simulation with GPU (Graphics Processing Unit) computing technology.

The simulator which we used is TOUGH2/ECO₂N developed in Lawrence Berkeley National Laboratory. The TOUGH2 series has a massively parallel version of the TOUGH2 code called TOUGH2-MP. TOUGH2-MP is designed to perform parallel simulation on multi-CPU (Central Processing Unit) computational platforms. Therefore the simulation of TOUGH2-MP is higher-speed than it of TOUGH2. However, TOUGH2-MP is not suitable for a lot of simulation like Monte Carlo simulation because operation efficiency per one CPU core deteriorates.

We used GPU not a multi-CPU platform to accelerate simulation of TOUGH2. The parallelization of the operation processing is important to accelerate simulation with GPU. The operation processing algorithm of the TOUGH2 code is data dependency. But we realized the parallelization by applying the following algorithm.

- Multi-Color Ordering
- Cuthill-McKee Ordering
- Matrix storage methods such as BSR or ELL

In addition, we applied the block incomplete LU factorization to improve convergence of the matrix solver. As a result, we achieved acceleration rate more than 5 times with the simulation for the realistic three-dimensional reservoir model of about 110,000 grids. Execute time of the simulation was shortened to 20%. More acceleration is expected by optimization, but it depends on the problem. When the number of the grids of the reservoir model increases, the acceleration rate of the simulation becomes higher.

The statistical evaluation of the reservoir model with the consideration of uncertainty is enabled by executing Monte Carlo simulation with TOUGH2 accelerated by the GPU.