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# A Domain Decomposition Approach for Large-scale Multiphase Flow Simulation

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Large-scale simulations for multiphase fluid flow and heat flow are usually needed for solving real-world subsurface environmental and resource problems, such as nuclear waste disposal, CO2 geologic sequestration, environmental assessment and remediation, geothermal reservoir engineering, and gas hydrate investigation. Because these large-scale simulations require intensive computational efforts, many modeling studies are limited by problem size and process complexity. With the rapid progress in computer hardware, multi-core PCs, Linux clusters, and super-computers become common place, and parallel processing and computational methods become more and more practical and popular for their application in reservoir simulation. In this study, we present a domain decomposition approach for large-scale multiphase simulations using parallel computation. The approach partitions a model simulation domain into a number of small sub-domains, to be modeled simultaneously using multiple processes. Each process is assigned to be in charge of one portion of the simulation domain for updating thermophysical properties, assembling mass and energy balance equations, solving linear equation systems, and performing other local computations. The linear-equation systems are solved in parallel by multiple processes with a parallel linear solver. The multiple processes are run in parallel on shared- or distributed memory multiple-CPU computers, or even on single-CPU computers. A hybrid approach, running multiple processes in each CPU and using multiple CPUs, may get additional speedup. During solving a problem, communication between processes are needed to update sub-domain boundary parameters. A very efficient inter-process communication scheme has been developed. The new approach was implemented into the TOUGH2 code, a general-purpose numerical simulation program for multi-dimensional fluid and heat of multiphase, multi-component flows in porous and fractured media. The proposed approach demonstrates an excellent speedup. For most large-scale problems, this method is able to obtain super-linear speedup which may indicate when a problem is solved using multiple processes requiring less time than using simple process on single CPU. The super-linear speedup phenomena greatly benefit parallel computation. In this paper, we will apply the domain decomposition approach to simulate CO2 geological sequestration in saline aquifer with multi-million gridblocks, and the super-linear speedup phenomena will be investigated.