Implementation of Parallel Computing for Multiphase Flows using the Lattice Boltzmann Method

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Introduction
- 33 million gallons of radioactive waste at Hanford site
- Stored in leaking single shell tanks (SST)
- Double shell tanks (DST) introduced in 1968
- Unlike the SSTs, DSTs show no leaking
- Waste is being transported from SSTs to DSTs
- Transport of heterogeneous waste clogs piping
- Pulsed-air mixing used to “stir” heterogeneous material
- LBM simulates bubbles rising to predict mixing

Parallel Processing Background
- Master processor divides the problem domain amongst multiple slaves
- Message passing interface (MPI) allows CPUs to bridge information across sub domains
- Reduction of processing time is ultimately limited by communications between processors and the components of the program that must run sequentially
- Effectiveness of parallelization is measured by speedup, S(N), for N processors
- When increasing the number of CPUs shows minimal performance increase, optimal quantity has been reached

Amdahl’s Law:
\[ S(N) = \frac{T(1)}{T(N)} \]

Laplace’s Law:
\[ \Delta P = \frac{\sigma}{R} \]

Methodology
- Lattice Boltzmann method is based on the Boltzmann transport equation
- Domain is discretized with lattice nodes instead of rigorous meshing
- Independence from mesh allows for complex domains like porous media
- Masses at nodes collide and stream information to neighbors

Validation of the Parallel LBM Code
- Overlapping profiles for serial and parallel case indicates accurate results for parallel code
- For 640,000 nodes, the parallel code reduces the job from thirty hours to only three hours
- Speedup trends, near-linear behavior confirms correct parallelization

Conclusions and Future Work
- Parallelization with the optimal number of processors results in significant savings in computer time (10 times for N=25 and 640,000 lattice nodes)
- Parallelization allows for simulation of larger domains or longer times
- Future work will include extension of the code from 2D to 3D
- In addition, fluid-solid interactions will be also implemented

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