**Modeling flue pipes:**
**subsonic flow, lattice Boltzmann,**
**and parallel distributed computers**

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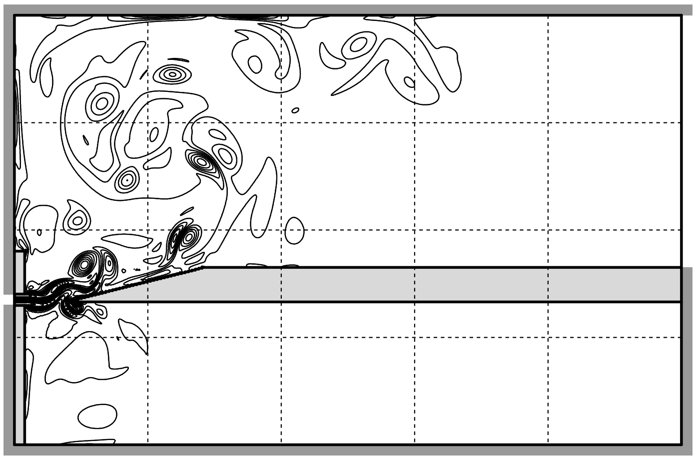
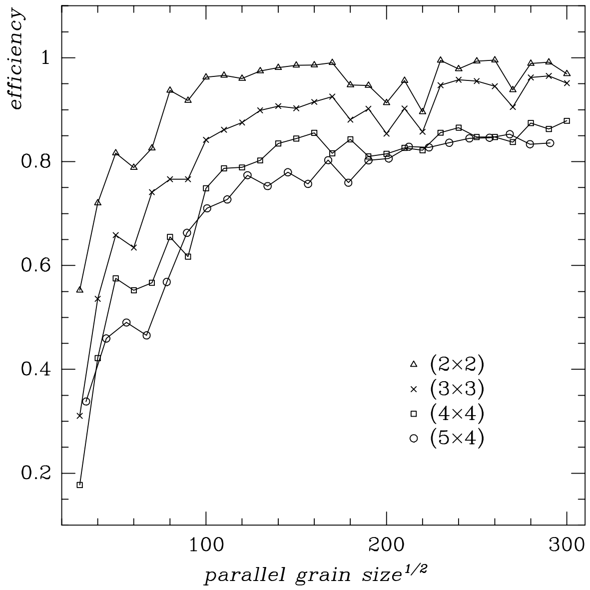


Simulation of a flue pipe using 20 workstations in a $5 \times 4$ decomposition (dashed lines).




The parallel efficiency (speedup/processors) is shown for 2D simulations of subsonic flow using 4,9,16, and 20 workstations. The efficiency is plotted against the square-root of the number of fluid nodes per subregion, where each subregion is assigned to a different workstation. The lattice Boltzmann numerical method is used.

**Summary**

- The problem of my thesis is the simulation of the hydrodynamics and the acoustic waves inside wind musical instruments such as the organ, the recorder, and the flute. Such simulations have never been done before.
- I simulate the flow of air and the generation of musical tones inside flue pipes. I physically measure the acoustic signal of various flue pipes, and find good agreement with the simulations.
- Previous attempts at this problem have been frustrated for two reasons: First, the modeling of acoustic waves requires small integration time steps which make the simulation very compute-intensive. Second, the simulation of subsonic compressible flow at high Reynolds numbers is susceptible to slow-growing numerical instabilities which are triggered by high-frequency acoustic modes.
- I mitigate the problem of numerical instabilities by employing a fourth-order artificial viscosity filter. The filter can be used both with the lattice Boltzmann method and also with a compressible finite difference method. I develop a technique for accurate initial and boundary conditions for the lattice Boltzmann method, and I also demonstrate the second order accuracy of the lattice Boltzmann method.
- I handle the problem of compute-intensive requirements by developing a parallel simulation system on a cluster of non-dedicated workstations. The system achieves 80% parallel efficiency (speedup/processors) using 20 HP-Apollo workstations in a cluster where there are 25 machines total. The system is built on UNIX and TCP/IP communication routines, and includes automatic process migration from busy hosts to free hosts.