Parallel Performance for a Real Time Lattice Boltzmann Code

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Abstract

The paper will present the details of a Lattice Boltzmann solver running in real time for unsteady wake computations. In addition to algorithmic implementation, computational results, single core and parallel optimization of the methods are also discussed.

Keywords: Real-Time Lattice Boltzmann Method

1. Introduction

Computational Fluid Dynamic (CFD) methods have become increasingly sophisticated and accurate over the past 20 years. However they are orders or magnitude too slow for real time flow computation and so, analytical models or simplified aerodynamic models are still used if real time estimates are necessary, like for example in flight simulation.

Recently, lattice Boltzmann methods (LBM) have emerged as an alternative to the more traditional methods for simulating fluid flow. The LBM was developed as an extension to lattice gas automata and a review of the developments can be found in Aidun and Clausen (2010). Khan et al. (2015) demonstrated the use of the LBM, implemented on a graphic processor unit (GPU), running real time simulations for indoor environments.

2. Results

The single core and parallel performance can be seen in figure 1. Optimizations enabled the LBM to run between 15 and 20 Million updates per second depending on block size on a single core of a Intel Xeon E3-1245 running at 3.30GHz. The parallel performance within an ARCHER node (ARCHER is the UK National Supercomputing Service) shows about a 50% scaling while scaling across nodes is excellent. The efficiency of the current implementation is mainly due to the simultaneous execution of the LBM iteration i.e. macroscopic calculation, collision and streaming, and minimizing the redundant calculation. Figure 2 shows the real time flow around the cylinder. The lattice size was set to 600×100 with a lattice spacing of 0.01, the lattice velocity

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Method	MUps
Original	4.13
Improved Streaming	5.93
Computation removal	10.52
Single loop	17.53
Small block version	19.93

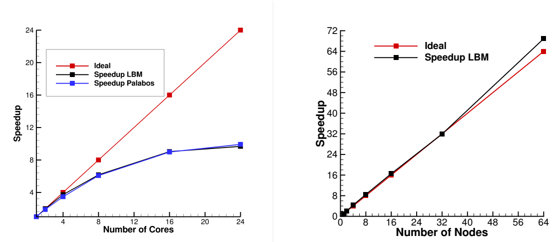


Fig. 1 – The speedup curve for running LBM within and across ARCHER compute nodes - (Two 2.7GHz 12-core E5-2697 v2 Processors)

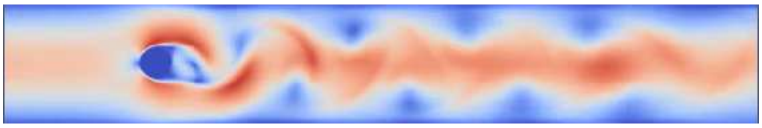
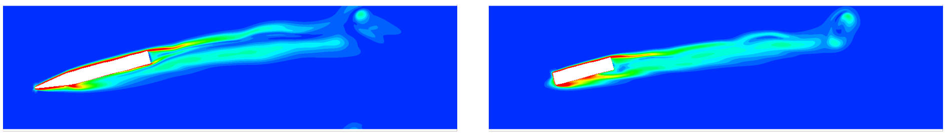


Fig. 2 – The velocity magnitude for flow around a cylinder

is 0.1 and the Reynolds number 1000. This means that 1000 time steps are required to simulate a second a real time. With the given lattice size that means at least 60 Million lattice updates a second are required which is possible within a single ARCHER node.



Timestep = 8800 below deckline　　Timestep = 8800 above deckline

Fig. 3 – The vorticity magnitude for flow around the SFS2 at 15 degrees.

Figure 3 shows flow around the Simple Frigate Shape 2 (SFS2) also computed with conventional CFD by Crozon et al. (2014). The lattice was $900 \times 100 \times 240$ the required performance need to obtain a real time computation is of the order of 30800 million updates a second or around 240 ARCHER nodes or some 5760 cores.

3. Acknowledgments

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