Application of high performance computing on volumetric velocimetry processing

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Keywords: volumetric velocimetry, LSM, voxel reconstruction, GPU

This paper examines the use of graphical processing units (GPU), a technology that has received considerable fanfare in today’s scientific community, in processing and analysing data for volumetric velocimetry applications. GPU’s are highly parallel devices that while lacking the data management characteristics and flexibilities of CPU’s can execute parallel tasks at a far superior rate. CPU’s found in personal computers today typically contain 1 to 8 cores. GPU’s, on the other hand, can be found with up to 512 cores, with the additional possibility of connecting several (up to four in a single pc) of these devices together. GPU implementations of volumetric applications in general experience a 30-50-fold improvement over CPU implementations.

1. Introduction

Least-Squares Matching (LSM) or Least-Squares Tracking (3D-LST), is ideal for parallel computation since the problem is dissected into many small, regularly sized cuboids that can be independently evaluated. Originally applied for tracking structures in LIF (laser induced fluorescence) applications, LSM applies deformation and rotation to cuboids in an iterative fashion, using a least-squares adjustment procedure to determine the affine transformation between a gray cuboid at time t₁ and t₂. The resulting affine transformation contains 12 parameters: for translation, scale, rotation and shear.

To test the processing capabilities of the GPU’s, the results from another volumetric investigation were employed as input data. A descending toroidal vortex was captured via three time-resolved cameras while illuminated by a volumetric light source. Two consecutive frames from each camera were used in the voxel reconstruction. The resulting reconstructed volume for this application was 10 x 10 x 1 cm. The experimental setup consisted of a large quiescent tank, octagonal in form to ensure orthogonal orientations of the cameras.

2. Results

The bulk of the processing time for LSM takes place in the iterative deformation of the cuboids, which require efficient three-dimensional interpolation schemes. The processing of interpolations alone were an impressive two orders of magnitude faster than on a typical workstation CPU. The fact that the time does not increase appreciably with increasing volume size points to the overhead of kernel execution.

In total, a 128-core GPU could process a 25 x 25 x 25 cuboid 20-30 times faster than an 8-core CPU. The 256-core GPU (Tesla) could interpolate a cuboid 40-50 times faster than an 8-core CPU. In addition, other processes such as matrix multiplication, inversion, equation solving were all markedly faster on GPU’s than on the CPU.

![Fig 1. Performance comparison between GPU and CPU for deformation processing of one cuboid](image-url)