FFT based Medical Image Registration Using a Graphics Processing Unit (GPU)

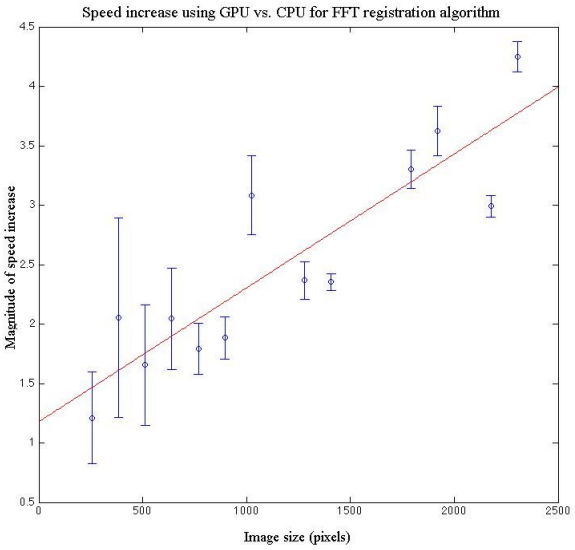
Image registration plays an important role in modern radiotherapy. The process of registration is used not only for treatment planning but also plays an important role in treatment verification. As such, the evaluation and implementation of image registration algorithms is an important endeavor.

Recently, we have been investigating the use of Fourier Transform (FT) based registration. FT algorithms have been utilized in other fields (eg., satellite image registration), but to our knowledge, have not been examined in the context of radiotherapy. Consider two images $f_1(x,y)$ and $f_2(x,y)$, where f_2 is a translation of f_1, i.e. $f_2(x,y) = f_1(x-x_o,y-y_o)$. Their FT are given by $F_2(u,v) = F_1(u,v)e^{-2\pi i(uxo+vyo)}$.The shifts, x_o and y_o, can be determined by taking the inverse FT of the cross-power spectrum F_1 and F_2. The result is a Dirichlet delta function with it's peak centered at the coordinates of the translation (x_o,y_o). Rotations and scaling can also be recovered using the same method on the log-polar transform of the Fourier transformed images.

There are three principle advantages of the FT algorithm. First, by resizing the images, translations and rotations can be obtained with sub-pixel accuracy. Secondly, FT based registration is computationally efficient through the use of the Fast FT (FFT) algorithm. However, as the image size increases, there are limits on the computational efficiency of the algorithm. The third advantage of the FT based algorithm is that FFT calculations can have a substantial speedup using Graphics Processing Units (GPU).

The benefits of using a GPU are most apparent when the exact same operation needs to be performed on all the elements in a pixel array. This is because a GPU consists of hundreds of individual processing units that can work in parallel to compute a matrix operation in tandem faster than a single CPU can compute it sequentially. As the FT accounts for approximately 87% of the computational time needed by the CPU to perform the registration algorithm, it is expected that implementation on a GPU would provide a substantial speedup to this method.

To test this hypothesis, a FT registration algorithm was written in Interactive Data Language (IDL; Exelis, Boulder, CO) to perform CPU-based calculations [1]. Subsequently, the program was modified using GPU bindings (Tech-X, Boulder, CO) to perform GPU-based computation on the same system [2]. The CPU used was a Dell Optimex 755 Dual Core Processor, and the GPU used was a Nvidia GeForce GT 240. A single set of medical images with a known translation were registered, with the image resized to values ranging from 256x256 to 2304x2304. The time required to complete the full algorithm by the CPU and GPU were benchmarked and the speed increase (i.e. the ratio of the CPU time to GPU time) was compared versus the size of image being registered. Any speed increase greater than 1.0 indicates the GPU is performing operations faster than the CPU. The figure shows the average time (over ten trials) needed by a CPU and GPU to perform the algorithm. As it can be seen, using a GPU results in an overall speed increase in computation time. This suggests further investigation into the use of GPUs for FT-image registration is warranted. We are currently investigating the clinical utility of the GPU-based FT image registration technique.



References:

1. Xie, et al. Computers & Geosciences 29 (2003) 1045–1055

2. Messmer, et al. Computing in Science and Engineering, September/Oct 2008, 80-83