GPU Accelerated Medical Image Registration Techniques

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Abstract— **Graphics processing unit (GPUs) are used in wide range of application now a days particularly Medical image processing in GPU becomes popular recently. Medical imaging procedures are often computationally demanding due to three dimensional data sets. With enhancing performances of graphic processors, improved programming support, GPU has emerged as a competitive parallel computing platform for demanding tasks in medical imaging. Image registration, segmentation and visualization are some of the challenges in medical image processing. This paper review about the current GPU image registration techniques in medical imaging, the most commonly used Image registration algorithms in medical imaging, the potential advantages and its challenges which will help the researchers or starters in GPU computing.**

Keywords- Graphics processing unit (GPU), Image registration, CUDA, High performance computing.

I. INTRODUCTION

Parallel computer systems have been available commercially for many years. Parallelism is the future of high performance computation in medical applications. Graphical processing units (GPUs) are powerful parallel processors mostly dedicated to image synthesis [1]. GPU is always designed for a particular class of applications with the following characteristics [2]: i) large computational requirements, ii) parallelism and iii) throughput. Recent graphics cards provides highly parallel architectures (hundreds of processing units) with high memory bandwidth while CPUs reach 50 Giga FLOPS [1] and become a competitive platform for high performance computing. GPU providing a functionally complete set of operations performed on arbitrary bits can compute any computable value. Additionally, the use of multiple graphics cards in one computer, or large numbers of graphics chips, further parallelizes the already parallel nature of graphics processing [3]. Only the researchers familiar with graphics API's can use the GPU platform which makes inconvenience to unfamiliar users.[4].

CUDA is a parallel computing platform and programming model invented by NVIDIA. It provides great flexibility in computing performance by binding the power of the graphics processing unit (GPU) which prevail over the drawbacks exists in current GPU/GPGPU to certain extent. For the ease of general purpose parallel programming on the NVIDIA GPU, CUDA provides C like development environment to programmers [5]. In addition to libraries, compiler directives, the CUDA platform supports other computational interfaces, including the OpenCL, Microsoft's Direct Compute and C++ AMP. CUDA has been widely used in various applications including molecular dynamics, fluid dynamics, and computer vision and so on. The aim of this review is to give the readers a general idea about GPU based image registration techniques, and to discuss parallel approaches to many algorithms used for image registration.

II. GPU ARCHITECTURE AND PROGRAMMING

A short introduction to the GPU architecture offers better understanding. Modern GPUs has number of multi-processors, each containing a number of processor cores and memory chips with very high bandwidth [8]. Each thread block is executed on a single stream multiprocessor, which is made up of a set of cores. The threads are organized into blocks of threads within a grid of block [7]. The data is copied from the CPU to the GPU's global memory. All threads will start reading data from global memory into the local registers, and end by finally writing the result back to global memory when the calculations have been completed. To facilitate cooperation between threads in a thread block, a small shared memory (16-48 KB) at each multi-processor is available to exchange data efficiently.

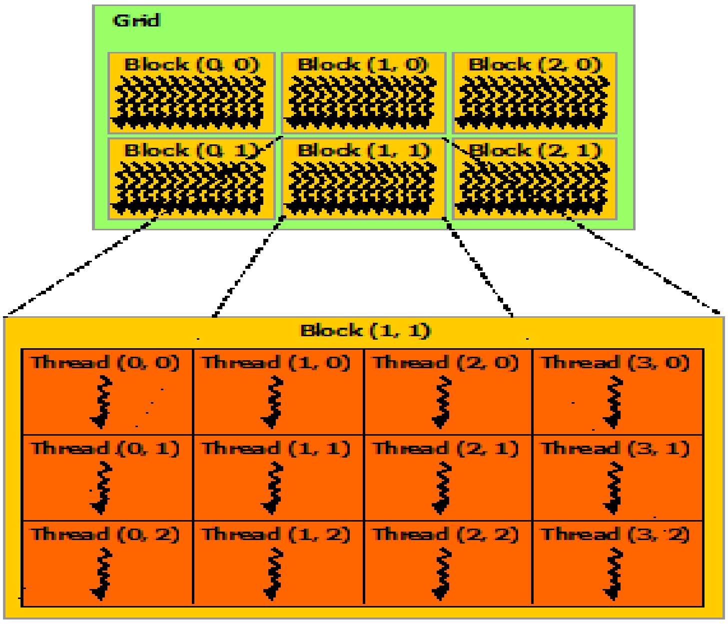

Fig.1. A Conceptual framework of CUDA Programming model.

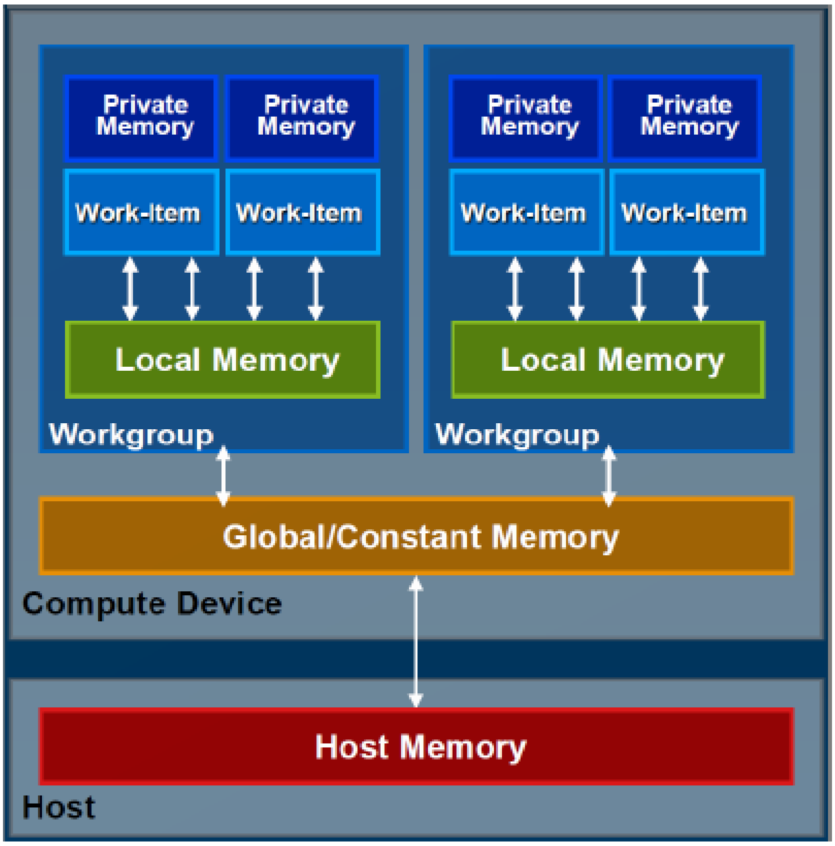

Fig.2 Internal structure of OpenCL taken from reference [15]

To simplify fast development of optimized code, NVIDIA has released a number of CUDA libraries for different purposes. Some examples are CUBLAS (basic linear algebra operations, dense matrix operations), CUFFT (fast Fourier transforms in 1,2, and 3 dimensions), CURAND (random number generation),NPP (NVIDIA performance primitives, functions for image processing),thrust (sorts, searches, reductions) and CUSPARSE (sparse matrix operations). The thriving CUDA community has also produced several non-NVIDIA libraries as well, including MAGMA1 and CULA2, which both contain functions for matrix algebra. ArrayFire3 contains a broad variety of functions and also includes support for OpenCL [8].

III. MEDICAL IMAGE REGISTRSATION

A. Definition

Image registration is the process of lay over images of the same scene taken at different times, from different viewpoints, from variety of sensors. Typically, registration is essential in medicine combining computer tomography (CT) and NMR data to obtain more complete information about the patient, monitoring tumour growth, treatment verification, and comparison of the patient's data with anatomical atlases [10]. In medical applications, images of similar or inconsistent modalities often need to be aligned as a pre-processing step for planning, navigation, and data-fusion and visualization tasks [11]. In general, the medical image registration should establish correspondence measure between a reference image, I_r, and a target image, I_t, using a parameter transformation, $T_t(.)$, of image geometry in line with a similarity function, ρ(.), to specify the registration performance. When two images have different dimensions, projection operators, P_r and P_t, may be incorporated to project a higher-dimensional image domain into a lower-dimensional image domain. Then, the image registration problem can be expressed via maximizing the following similarity measure function [12]:

$$T_t(.) = avg\ max\ \rho\ (P_r(I_r), P_t(T_t(I_t))) \qquad (1)$$

B. Methods

As shown in [13,14], the image registration procedure consists of following 4 steps

Feature detection:. In this stage salient and distinctive objects are manually or automatically detected. For further processing, these feature scan be represented by their point representatives which are called control points (CPs).

Feature matching: In this stage, the connection between the features detected in the sensed image and those detected in the reference image is established.

Transform model estimation: The type and parameters of the so-called mapping functions, aligning the sensed image with the reference image, are estimated. The parameters of the mapping functions are computed by means of the established feature correspondence.

Image resampling and transformation: The sensed image is transformed by means of the mapping functions. Image values in non-integer coordinates are computed by the appropriate interpolation technique.

Gao et al. [17] uses ray casting approach to perform registration between 3D trans-esophageal echo cardiography and X-ray fluoroscopy images. Spoerk et al. [18] made a comparison between ray casting and wobbled splat rendering for registration between CT volumes and X-ray images. Dorgham et al. [19] proposed faster rendering by sparse sampling. With a satisfactory image quality, a DRR of a CT volume comprised of 256 × 256 × 133 voxels could be generated in 2ms. Steininger et al. [20] compared three similarity metrics and found that rank correlation performed best. Yuen et al. [21] presented a real-time motion compensation system for ultrasound volumes, such that mitral valve repair can be performed while the heart is beating. Brounstein et al. [22] focused on the problem of registration between pre-operatively acquired CT scans and time resolved ultrasound data, by using an approach based on Gaussian mixture models and local phase. The registration could be performed in about 2 seconds; while several ultrasound systems can generate volume data at a frame rate of about 25 Hz. Ruijters et al. [23] reported a fast implementation for non-rigid registration between pre- and intraoperative cone-beam CT volumes. Other recent examples include GPU accelerated images registration of MRI images [24, 25, 26] diffeomorphic image registration algorithms [27, 28], Fast free-form deformation using GPU (Modat et al.,) [29], motion tracking of video microscopy through image registration (Liu et al.) [30] and mass-conserving image registration (Castillo et al.,) [31]. Lee et al. [32] described how to optimize GPU implementations that are compute and memory-bound and apply it to image registration. Their optimization strategies resulted in a speedup of a factor 6, compared to a naive GPU implementation Except for the work by Brounstein et al.[22], the previous citations have used image registration algorithms that are based on the image intensity. A less common approach is instead use phase-based image registration. The main advantage of the local phase is that it is invariant to the image intensity. Phase based optical flow was introduced in the computer vision field by Fleet and Jepson in 1990 and eventually propagated into the medical imaging domain by Hemmendor_ et al., in 2002. Mutual information-based image registration by Viola and Wells[33] and Pluim et al., [34] is often acknowledged for its ability to perform multi-modality registration, but phase mutual information can in some cases perform better (Mellor and Brady[35,36]; Eklund et al.,[37]. However, a general drawback of phase based image registration is the increase in computational complexity; several non-separable filters have to be applied at each iteration. Pauwels and Hulle [38] therefore made a GPU implementation of phase-based optical flow in 2D, using Gabor filters.

Eklund et al. [39] instead used quadrature filters for phase-based a new volume registration and Knutsson and Andersson, [40] used the GPU to accelerate the Morphon which is a phase-based non-rigid registration algorithm. In each iteration, the local structure tensor [41, 42] is used to improve the registration. Three dimensional convolution with six complex valued (12 real valued) non-separable quadrature filters are required to estimate a phase invariant tensor. These work, although few, demonstrate that the GPU also can be used to enable more advanced registration algorithms. (AlhusseinFawzi et.al 2013) propose a registration algorithm for sparse images that are given as a linear combination of geometric features drawn from a parametric dictionary. Hong Zhang et.al proposed an ant colony optimization image registration based on wavelet transform and mutual information [16].

IV. CONCLUSION

Image registration is one of the most important tasks when integrating and analysing information from various sources. It is a key stage in image fusion, change detection, super-resolution imaging, and in building image information systems, among others.[10] and GPU is one of the main standard tool in high performance computing . Researchers are showing more interest in utilizing the power of GPU. The main advantages of GPU based medical imaging is high throughput computing, high memory bandwidth cheap and specialized hardware's for interpolation [13]. General purpose computing with GPUs implies some challenges and technological issues. Platform dependency, Data transfers, Sequential to parallel processing, Varying relative GPU/CPU performances[1] These works, although few, demonstrate that the GPU also can be used to enable more advanced registration algorithms, which might otherwise be dismissed as being too computationally demanding[8] . The computation of the similarity measure and geometric transformation is the main bottleneck of image registration. Image registration algorithms is based on the assumption that each region in the reference image has a correspondence match in the target image, but in practical application there may not be a exact one to one correspondence match between the reference and the target image due to partial or missing data sets. The future research will be concentrated in image registration with partial or missing data [12] and rethink of approaches which will be suitable for massively parallel processing environment in real time practical medical applications.

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