High-Performance Medical Imaging Informatics

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1. Development of High Performance Computation in Medical Imaging

The topic of High Performance Medical Image Computing for Image-Assisted Clinical Intervention and Decision-Making is central for imaging informatics, since the amount and complexity of imaging data continues to grow as new modalities are added to the radiological repertoire in an increasingly distributed (and often cloud-computing) environment. This topic was the subject of the 2010 High Performance – Medical Image Computing and Computer Assisted Intervention (HP-MICCAI) Workshop on High Performance Medical Imaging, which we organized with a number of colleagues, and from which two papers are included in this issue of Methods of Information in Medicine as part of a Focus Theme.

Recent advances in acquisition, sensing and automated technology have generated an explosion of high resolution and high frequency medical image and video data. However, as the acquisition of massive data from the new modalities increases, so does the need for more efficient ways of processing the data in both clinical practice and clinical research environments. The effective and efficient interpretation of suites of complex medical images depends on how well and how rapidly they can be analyzed, and how effectively summarized. Proliferation of high resolution multimodality medical images and videos presents considerable challenges to both clinical practitioners and IT specialists. The value of the image datasets for time-critical clinical applications such as image-assisted surgery, cancer therapeutics, clinical decision-making, and multimedia data fusion and analytics, is undisputed. Conventional serial computation is inadequate and inefficient for handling a high volume of images of different modalities, and can significantly affect quality of care, by delaying diagnoses and treatments. High-performance (HP) computing holds the key for unlocking the full potential of medical imaging. More specifically, serial computation is inadequate for handling large amounts of medical image data because it typically involves computation times in the order of hours and often days and frequently must resort to sub-sampling of the data. Recently, exceedingly powerful computer hardware and optimized image processing software can, for the first time, allow high-volume image data processing and manipulation to become clinically feasible on a routine basis in real-time. High-performance computer-cluster, multi-processor, multi-core and many-core technology with high-volume throughput and vector processing capabilities promise to reveal the clinically useful information contained in medical imaging data and have a strong impact in transferring medical imaging research from the lab into clinical practice. Increasingly multi-disciplinary research efforts have sprung up to develop innovative designs, techniques and algorithms that ex-
ploit the full potential of these new computing platforms to match the demand for high accuracy and high speed in many important computer-aided clinical applications.

2. The HP-MICCAI Workshop

The HP-MICCAI 2010 workshop described collaborative efforts in understanding current trends in HP medical imaging research, exploring new ideas and techniques for image-assisted clinical intervention and decision-making. The Organizing Committee consisted of Leiguang Gong, IBM TJ Watson Labs, Casimir A. Kulikowski, Rutgers University, Jason Corso, SUNY at Buffalo, Daniel Blezek, Mayo Clinic, Rochester, and David Foran, UMDNJ-RWJ Medical School. Papers included computational methods, systems and applications focused on topics which included multi-core/multiprocessor and other parallel platform-based algorithms for HP image processing, segmentation, registration, reconstruction, rendering and visualization for the time critical applications in clinical environments, such as high-throughput image screening, image segmentation and reconstruction.

Parallel and distributed computing has played an increasing role in real time and scalable medical image analytics over the past decade, and two emerging trends have become consolidated in the past two years for applications of high performance computing in biomedical imaging: cost effective multicore/GPU desktop workstation-based medical image analysis and cloud computing-based medical image processing, communication, and workflow management. Qi et al’s paper is an example of the first trend and Sofka et al.’s paper is an example of the second trend.

Qi et al. [1] propose a GPU-based parallel algorithm and implementation of a fast automated segmentation method for locating and delineating touching cell boundaries for the analysis of imaged histopathology specimens in digitized tissue micro-array (TMA). The new segmentation method uses a mean-shift clustering technique to accurately identify the most salient image patches and a mean-shift based voting algorithm to determine the center of each individual, often overlapping, cell. A level set active contour based on the interactive model is then deployed to extract boundaries of individual cells. Improved segmentation results are achieved by accurately estimating the seed locations and using a repulsion term in the level set energy function to separate the overlapping boundaries. The GPU implementation of the algorithm achieves 22 times speedup compared to its sequential implementation and takes less than 0.2 seconds processing a high resolution 2D image of dimensionality 1392 × 1040. The new method has demonstrated effectiveness and efficiency, and shows promise for improved reliability in detection and classification tasks over a wide range of investigative and clinical cancer applications.

Sofka et al. [2] report on a cloud-based computing system for automatically detecting anatomical landmarks in 3D image volumes, responding to the growing need for image analysis services within cloud computing environments. The key challenge they address is the common problem of limited bandwidth between a (thin) client, Data Center (DC), and a Data Analysis (DA) server. The central idea of their proposed novel technique is automatic detection by progressive transmission of image regions or sub-images rather than the entire image. The algorithm first retrieves a coarse level image from the data server and produces a list of candidate landmark locations for further processing and analysis. These location candidates are then used to specify corresponding image regions at a finer resolution level. The process repeats for each of increasing resolution levels, and the robust mean of the strongest candidates obtained from each level is computed to determine the final detection of the landmark. For each cycle of processing, image data is transmitted by demand in terms of required sub-images at a needed resolution. The system has been shown to achieve at least 30 times bandwidth reduction without sacrificing accuracy.

These two papers are representative, but by no means cover all the significant research progress in the field of high-performance medical image analytics. However, their findings as well as those in other recent reports [3, 4] provide good examples of the growing trends of multicore- and cloud-based computing for medical imaging applications.

References