Iterative 3D PET Imaging on Networked Computer Clusters

J. Gregor and M.G. Thomason, Dept. Computer Science, University of Tennessee, Knoxville, TN 37996–1301.

Research Statement

Several iterative PET reconstruction algorithms have been proposed which all produce high quality images based on spatial statistics. A main concern with these algorithms is that they are computationally demanding, especially when having to process fully 3D data. Substantial computing power is readily available today as fast, dual-processor workstations and PCs, each equipped with large amounts of memory and interconnected by a fast local-area network to create a distributed computing environment. The objective of our research is to develop a framework that facilitates iterative 3D PET imaging on such inexpensive, networked computer clusters.

Focus of Attention (FOA)

We have previously shown 2D FOA to be a powerful, data-driven preprocessing scheme for reducing memory and CPU time requirements of the EM algorithm [1,2]. As illustrated in Fig. 1, the patient contour is estimated for the sinogram as well as the image. Most importantly, this is done in a way that allows the available computational resources to be focused on a significantly smaller linear system of equations than the one that otherwise would have to be solved. Quantitative and qualitative studies indicate that the internal physiological structure revealed by the EM algorithm is not compromised by the FOA preprocessing which, by the way, applies to the entire family of iterative PET reconstruction algorithms. The extension from 2D to 3D FOA is non-trivial, mainly because the theory of support functions upon which the former is based does not apply for the latter due to the 3D sampling geometry of a PET scanner being cylindrical instead of spherical. We are thus developing a 3D approach based on, but not identical to, 2D FOA. The goal is to estimate a patient contour which is as tight as possible, yet consistent within and between the sinogram and image data spaces; consistency refers here to having the correct number of unknowns and equations in the reduced linear system of equations that describes the photon emission and detection process. We expect 3D FOA to result in substantial computational savings.

Distributed Computing

When distributing iterative PET reconstruction across a networked computer cluster, more memory and CPU cycles become available. To make full use of these resources, data and computation must be evenly partitioned among the processors. But achieving a load balanced system may not be enough. Each processor must know what the other processors are doing at all times which necessitates networkwide exchanges of vast amounts of data following each iteration. While the time spent computing can be reduced in many ways (by means of faster algorithms, a larger cluster, etc), the time spent communicating will typically remain the same or even increase (the amount of data communicated is directly proportional to the size of the cluster) thereby making the network a bottleneck. Being able to reduce communication requirements is thus of utmost importance. One solution that we have investigated for the EM algorithm is to let the individual processors compute several local iterations before exchanging their latest results [3]. By delaying the communication, each processor ends up having to use *out-of-date* data. Convergence can still occur, however, provided that the multiplicative pixel update is constrained not to be too extreme at each iteration. We have also found FOA preprocessing to be extremely helpful [2]. Since each processor knows exactly what data is relevant and what data is being ignored, only the former need be communicated as the latter merely wastes valuable network bandwidth. Both approaches are being considered for the 3D PET imaging codes currently under development. Finally, we are in the process of writing software that facilitates the use of dual-processor computers by allowing shared-memory communication whenever possible as opposed to the more time consuming process of message-passing.

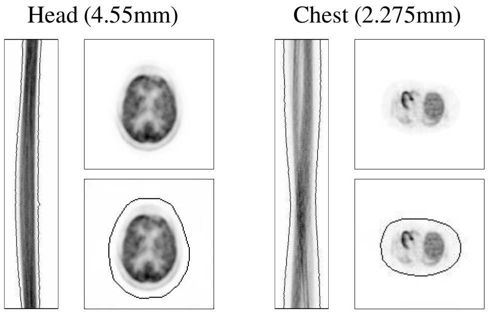

Fig. 1. Example reconstructions: (left) sinogram; (lower-right) image obtained after 32 iterations of the standard EM algorithm; (upper-right) result of applying FOA prior to reconstruction. The white regions, which are located outside the patient contours indicated by the solid black lines, illustrate data eliminated by FOA preprocessing.

References

[1] J. Gregor and D. Huff, “A focus of attention preprocessing scheme for EM–ML PET reconstruction,” *IEEE Trans. Medical Imaging*, **16**: 218–223, 1997.

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[3] S.P. Olesen, J. Gregor, M.G. Thomason, and G.T. Smith, “Parallel PET Reconstruction by EM Iteration with Reduced Processor Communications,” *Imaging Systems & Technology*, **7**: 215–223, 1996.