Real-Time GPU-Based 3D Ultrasound Reconstruction

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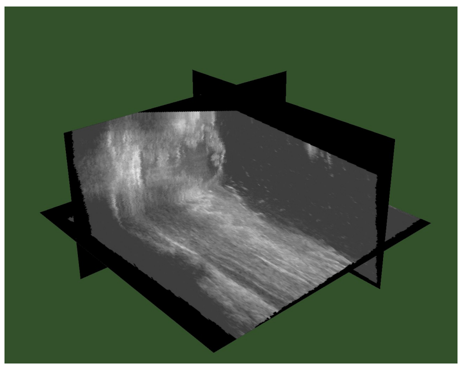
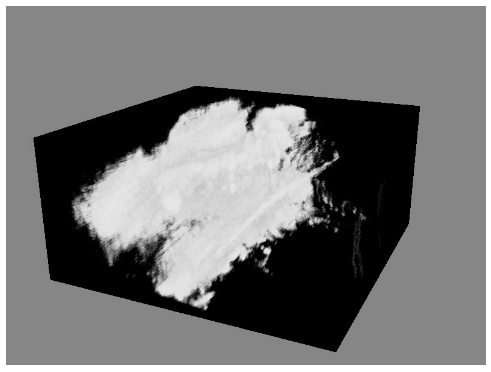
Ultrasound scanning is frequently used in medical practice because it is a non-invasive, safe and low-cost solution, but convential probes only provide 2D scans. Ultrasound reconstruction is to process such scans (*b-scans*) into 3D volumes of patient internals. The volume can be used for acquiring out-of-angle views, 3D rendering of the anatomy and image guided surgery. Being able to reconstruct in *real-time* as the data is acquired incrementally means that on can rescan areas of interest as observed on simultaneous real-time visualization.





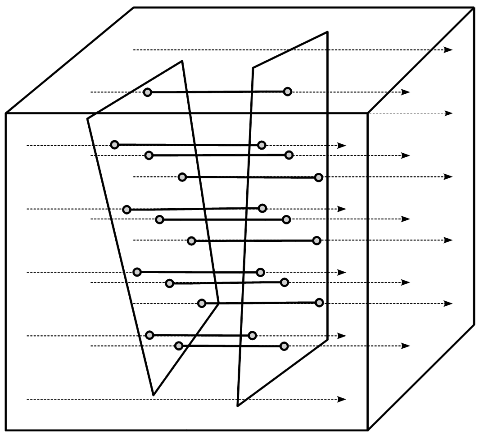


Fig. 1: Finding voxels between two ultrasound scans

The essence of the method is to transform incoming b-scan planes into the volume, an then only process voxels located *between* the b-scans. For each incoming b-scan, rays are constructed along columns of voxels and used for ray-plane intersection calculations with the current and previous b-scan planes (Fig. 1). To fill the voxels between the intersections, voxel-based interpolation methods can be used, and one alternative is based on distance weighted orthogonal projections [1] (DWOP), and a second one is based on cubic interpolation of the probe trajectory [2] (PT).

In DWOP, orthogonal projections are made of each voxel onto nearby b-scans. The pixel value at the projected points are weighted by the distance to the b-scan plane (Eq. 1).

$$voxel_j = \frac{\sum (pixel_i \cdot distance_i)}{\sum distance_i}$$

Eq. 1: Distance Weighted Orthogonal Projections

In PT, a virtual b-scan is created in the middle of four b-scans surrounding the voxel. The virtual b-scan is evaluated by cubic interpolation (Fig. 3), and the pixel values of the four interpolated b-scans are then weighted by orthogonal distance.

By utilizing the new Fermi GPU architecture by Nvidia, the incremental reconstruction is performed is real-time as the data is acquired as shown in Fig. 5. With 434 tracked b-scans. As for quality, the PT method demonstrated the best results (Fig. 2). The main bottleneck for performance is the overhead associated with data transfer between device and host for each increment.

This work shows how the parallel nature of ultrasound reconstruction can be exploited for real-time performance, and the techniques developed can benefit all who want to utilize the power of the GPU for reconstruction.

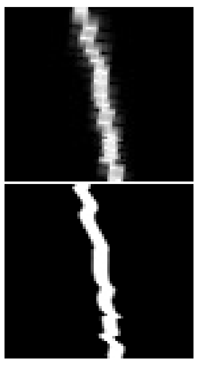


Fig. 2: Result of reconstructing straight lines (top: DWOP, bottom: PT)

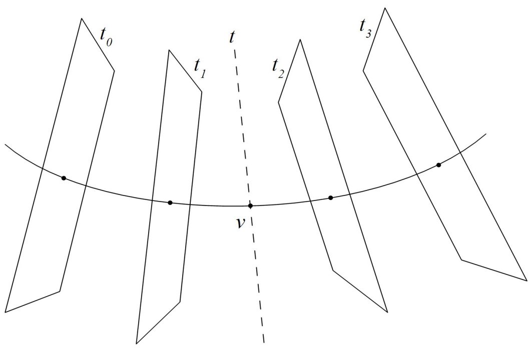


Fig. 3: Cubic interpolation for PT method

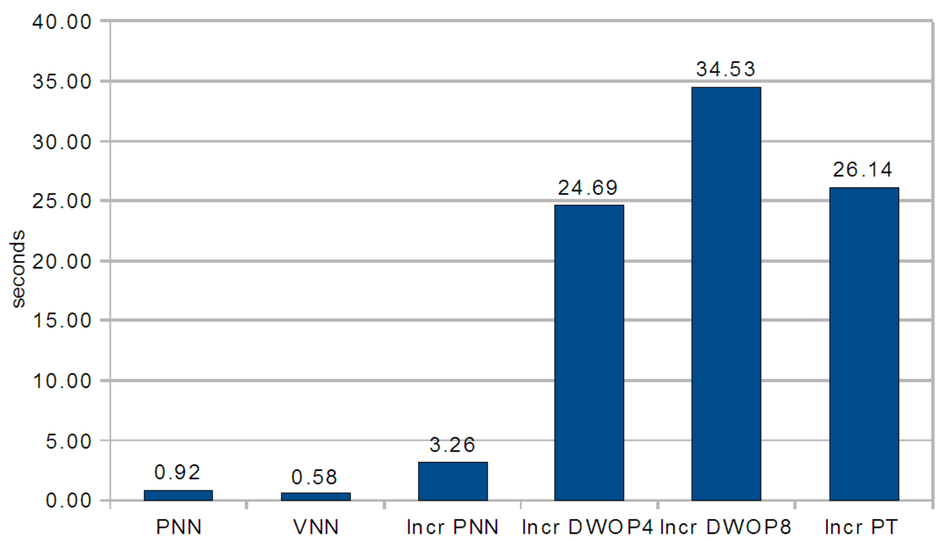


Fig. 5: Performance on Fermi (Tesla C2050)

[1] Trobaugh, J. W., Trobaugh, D. J., and Richard, W. D. Three-dimensional imaging with stereotactic ultrasonography. Computerized Medical Imaging and Graphics, 1994

[2] Coupe, P., Hellier, P., Azzabou, N., and Barillot, C. 3D Freehand Ultrasound Reconstruction Based on Probe Trajectory, Lecture Notes in Computer Science, 2005

Acknowledgements
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