**Texture Based Volume Rendering of Large-Scale Biomedical Data**

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Recent advances in commodity graphics hardware have enabled a new direct volume rendering technique based on 3D texture hardware. Hardware-based implementations usually have limitations in terms of the size of the volumes that can be displayed. We propose a new space sub-division technique combined with a wavelet decomposition scheme to enable a multi-level of detail rendering of data sets that are larger than the available texture memory on the graphics card.

Rather than displaying geometrical primitives and polygons, each discrete unit of space in the volume, known as a voxel, must be rendered. This results in the ability to see the internal structures and densities in the volume, and the smooth transitions between different materials within an object. This is especially useful for biomedical data, where organs have very complex structures and tissues rarely have clear surfaces and boundaries, instead they are composed of materials mixing together. The biomedical data sets are usually a series of many parallel cross sectional images, such as CT or MRI scans. Storing and managing each voxel in the entire volume means working with very large data sets, especially with continuing advances in scanner resolutions. This results in slow rendering times that can hinder user interactivity.

Instead of using established techniques such as raytracing to render each voxel, we store the volumetric data set on the texture buffer of the graphics card. This results in faster frame rates for rotation and translation of the volume data. The quicker rendering speed leads to better interactivity, allowing the user to more easily find the region of interest and extract specific features.

However, with very large scale data sets, the amount of data that needs to be rendered may be too large to directly fit into the texture buffer memory. The data must be reduced to obtain a lower resolution image to be placed in the texture buffer for displaying on the screen. The extra detail in the data set will be seen when the user zooms in by selecting a smaller sub-volume to be resampled and rendered at a finer resolution. This process is done efficiently by storing the data set in a hierarchical data structure in a preprocessing step.

First, the data is divided spatially in an oct-tree structure. By discarding empty regions, the total size of the data set is potentially decreased, allowing for faster transfer of data through networks.

A multi-resolution structure is achieved by performing Haar wavelet transformations in all three dimensions. The lower resolution data is stored at the beginning of the file and can be quickly loaded into the graphics texture buffer. The extra detail information is placed afterwards in the file and can be used to perform the wavelet reconstruction to restore the higher resolution images and make full use of the data set. This is particularly important for streaming volume rendering applications over networks.

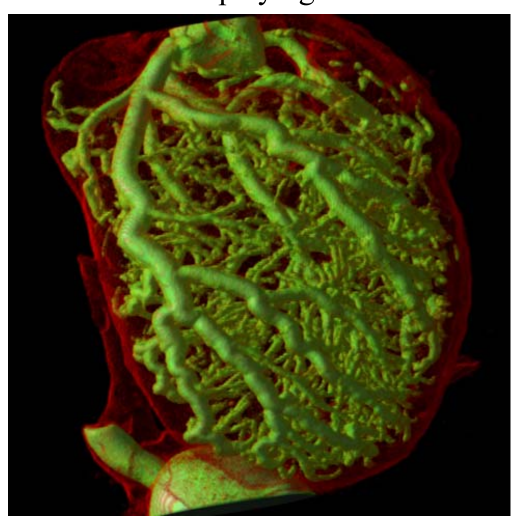

*Figure 1.* Direct volume rendering of a micro-CT scan of a mouse heart. (Data set courtesy of Ghassan S. Kassab, Biomedical Engineering Department, UC Irvine, and Erik L. Ritman, Mayo Clinic)