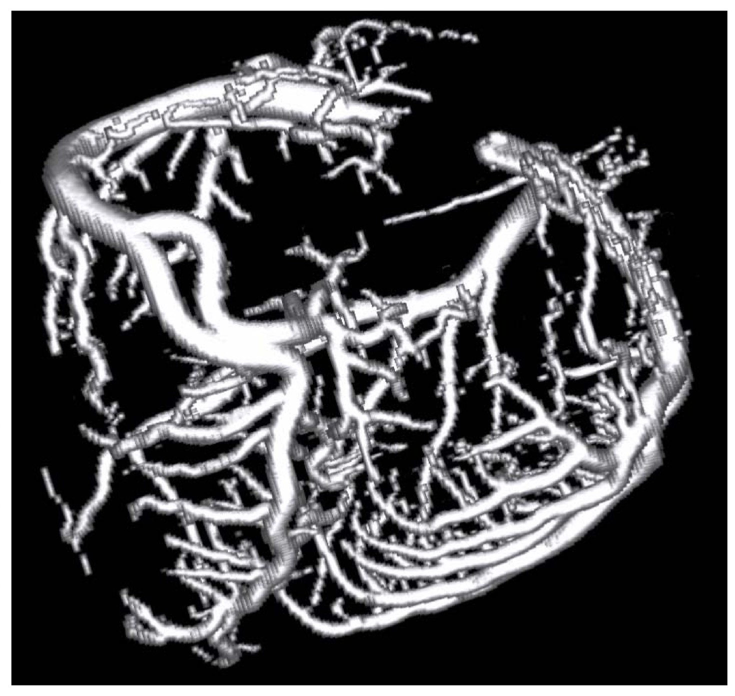
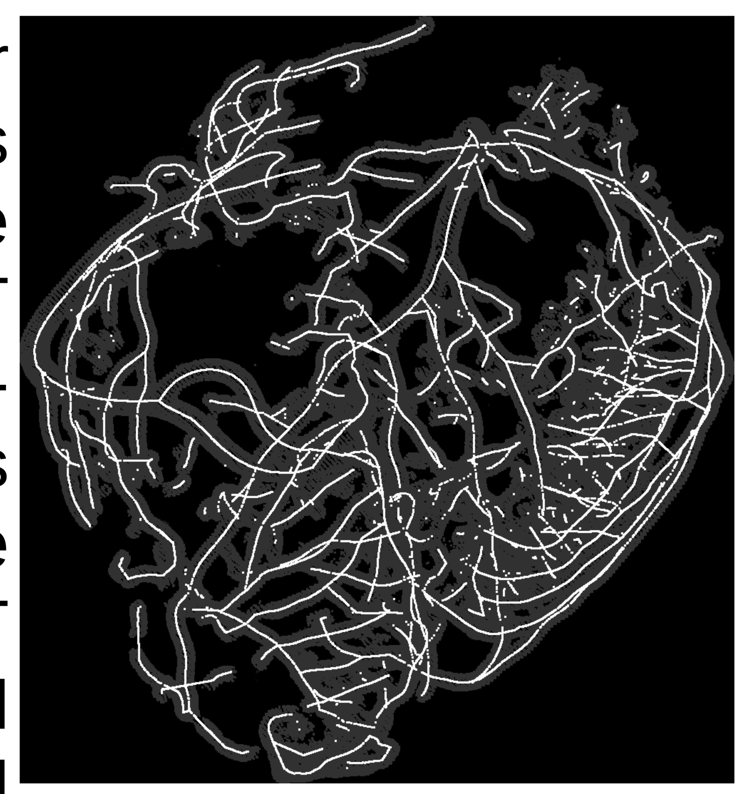
Analysis and Visualization of Vascular Structures

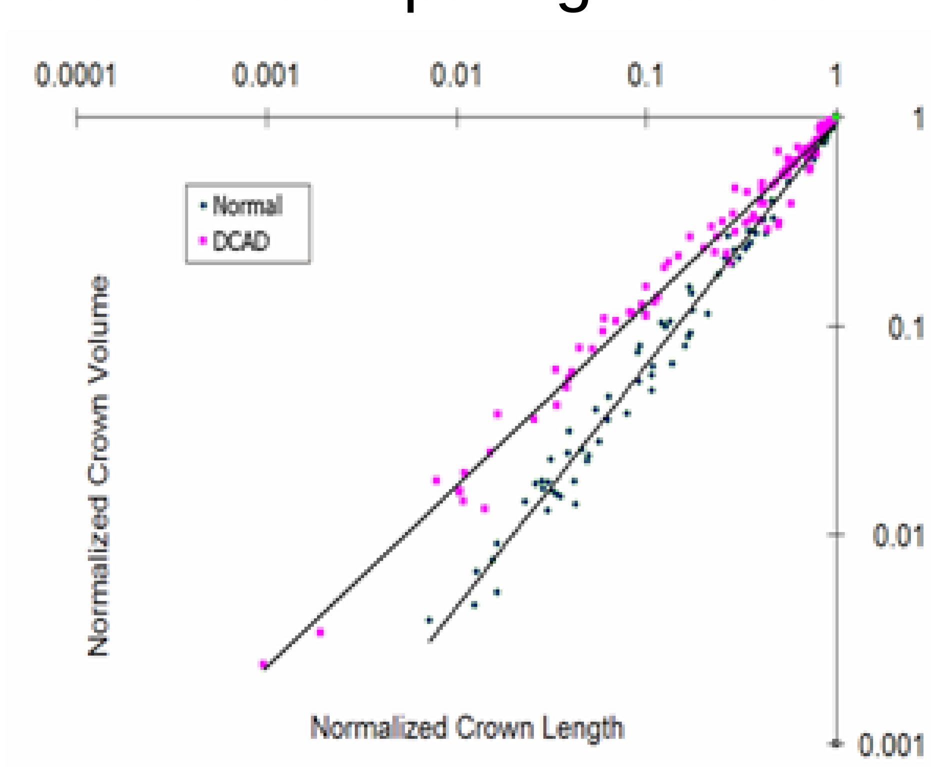
Thomas Wischgoll
Computer Science and Engineering
Wright State University

Diffuse Cardiovascular Disease

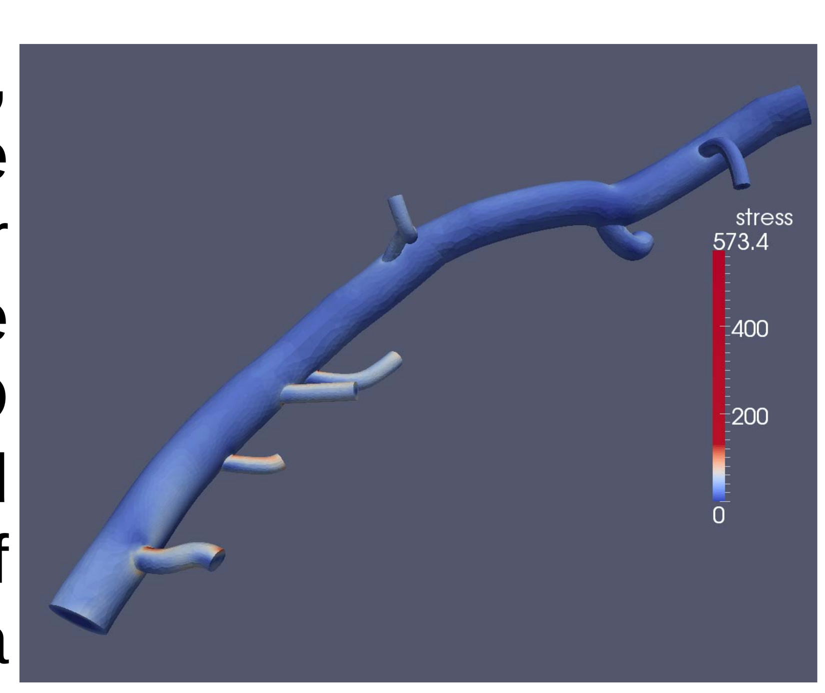




Volume visualization of volumetric data sets, such as CT scans, alone is not sufficient. To gain further information, quantitative data needs to be extracted which can then help in the diagnostic process. For example, computing the vascular volume in relation to the vascular length can indicate a diseased state if the relation is too small. In order to automatically determine this relation, advanced algorithms were developed that process a CT angiogram data set. A gradient-based segmentation step extracts the arterial vessels from the volumetric data provided by the CT angiogram. The resulting vessel geometry is then further processed to accurately identify the center lines of the vessels. The figure shows a volume rendering of the arterial vessels (top) compared to the extracted vessel geometry and the computed center lines (bottom). Based on the vascular geometry and the center lines, the software can then compute various quantitative measurements, such as vessel length, vessel radius, cross-sectional area, and vessel volume. Comparing the relation between vessel volume and vessel length for each crown in the arterial tree, i.e. the entire tree down from a bifurcation, shows that there is already a significant difference between healthy patients and patients with metabolic syndrome as indicated by the data plot.

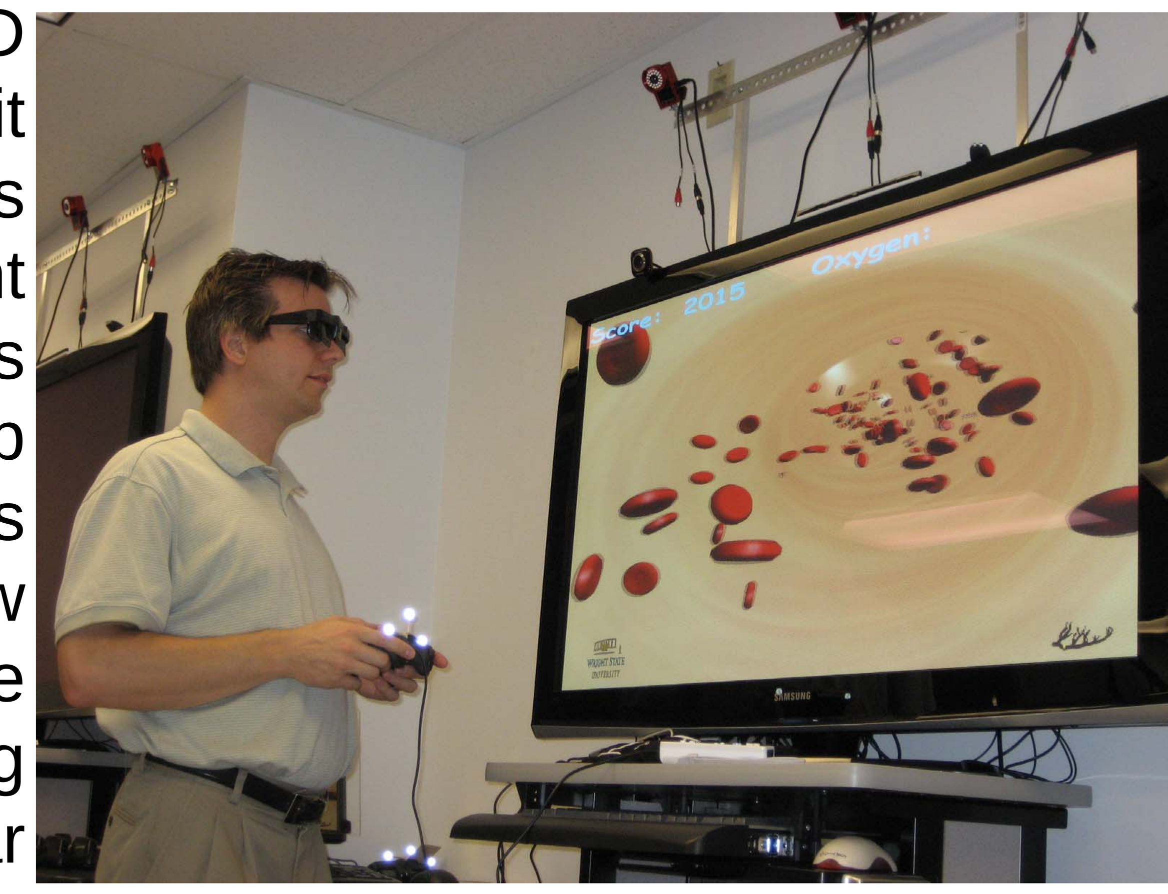


Visualizing Wall Shear Stress



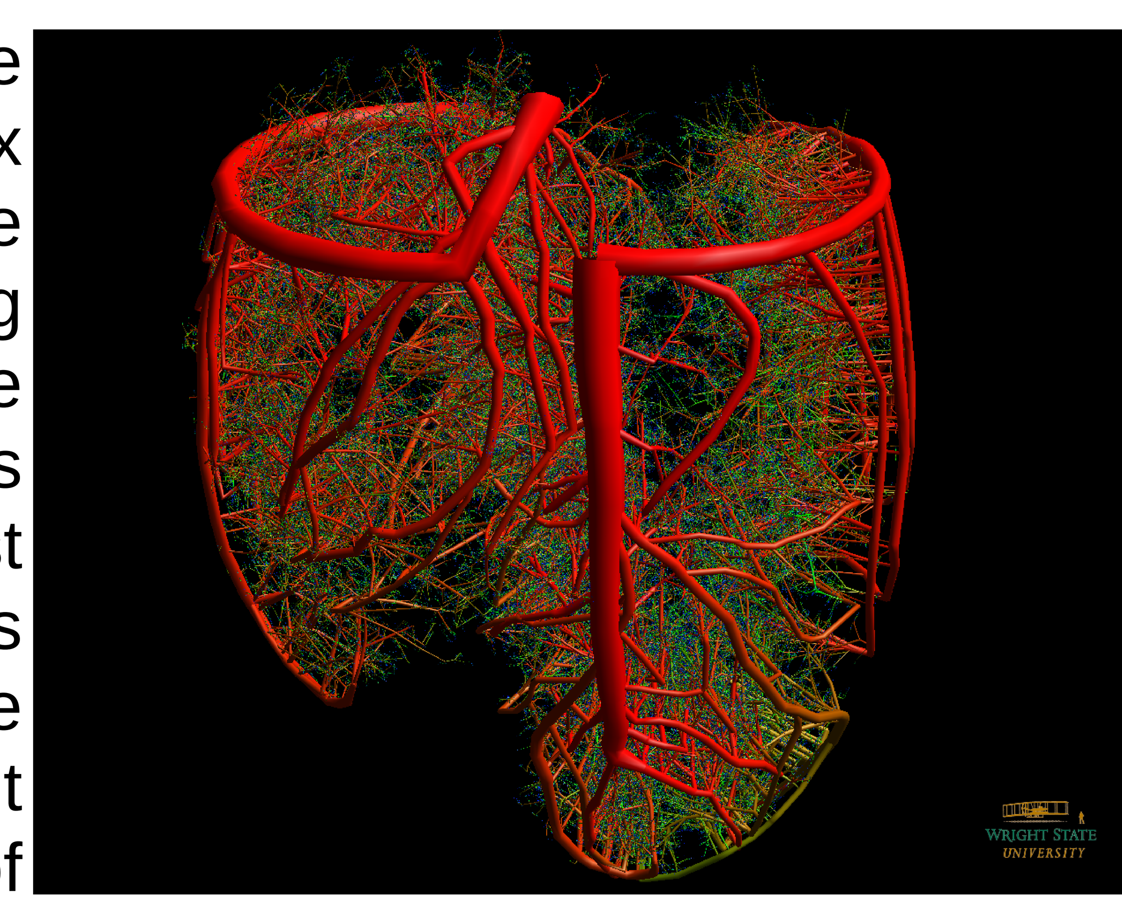
Based on the vascular geometry, a flow simulation can be performed. The vascular geometry serves as part of the boundary condition of the CFD simulation. Applying inflow and pressure at the incoming end of the vasculature based on a typical heart rate results in a simulated blood flow over time. At the same time, analytical data, such as wall shear stress or oscillatory shear index, can be computed.The figure depicts the wall shear stress values mapped onto the vessel wall using color coding.

Interactive 3D Exploration of Vascular Structures



Using 3D technology, as it nowadays appears in the entertainment industries, allows us to develop immersive systems at relatively low cost that are capable of showing the vascular structures in 3D. Utilizing active 3D shutter glasses enables the display system to present different images to the left and right eye, thereby allowing the brain to perceive a 3D effect. The figure shows such a setup, where an endoscopic view of a vascular structure is created. Using standard gaming controllers allows for a very intuitive navigation through the vascular structure.

Large-scale Visualization of Vascular Structures



Vascular trees are fairly complex structures. The geometry describing a vascular structure of a heart that ranges from the most proximal vessels down to the capilaries can result in several GBs of geometry data. When including both the arterial vessels as well as the venous system, the size of the data grows accordingly. This is often quite overwhelming for typical desktop computers. In order to visualize such massive structures on common desktop hardware, specialized rendering techniques can be applied to still be able to visualize the data. Such techniques include out-of-core rendering allowing the system to still render the data even though it exceeds the amount of physical memory present in the system. Similarly, algorithms that take visibility of the geometry into account can reduce the burdon on the graphics hardware, thereby improving the rendering performance. We developed techniques that are capable of rendering vascular structures exceeding 6 GBs in geometry data on typical desktop PCs with as little as 1 GB of main memory while still preserving a very high image quality of the resulting rendering of the vascular structure. The figure shows a vascular structure of a porcine heart that includes the most proximal vessels all the way down to the capillaries.