GENIUS: Grid Enabled Neurosurgical Imaging Using Simulation

Cardiovascular disease is the third largest cause of death in the developed world. Cerebral blood flow behaviour plays a crucial role in the understanding, diagnosis and treatment of the disease, where problems are often due to anomalous blood flow behaviour in the neighbourhood of bifurcations and aneurysms within the brain, although the details of such pathologies are not well understood. The GENIUS project uses blood flow simulation in combination with patient specific medical imaging data not only to help understand blood flow patterns in the presence of neurovascular pathologies, but also to provide a tool which surgeons can use in real-time to help plan courses of surgical treatment for the embolisation of arterio-venous malformations and aneurysms, *inter alia*.

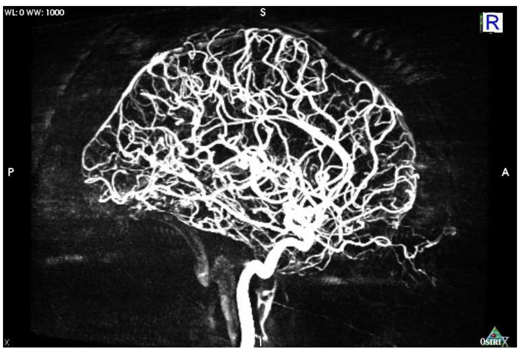

Figure 1: Raw 3D Rotational Angiography (3DRA) data of the arterial vasculature in the human brain

.

In order for patient specific medical simulation to function in a real-world setting, not only is the correctness of the results important, but their timeliness is imperative to the success of simulation methodologies. Various facets of high-performance computing are used to achieve this which go well beyond the batch-submission scenario typical in high-performance computing today: (a) *In situ* visualization; (b) real-time remote visualization and steering using RealityGrid steering; (c) distributed computing using MPIg; (d) advance reservations using HARC and urgent computing capabilities using SPRUCE; and (e) automated job launching using the Application Hosting Environment (AHE).

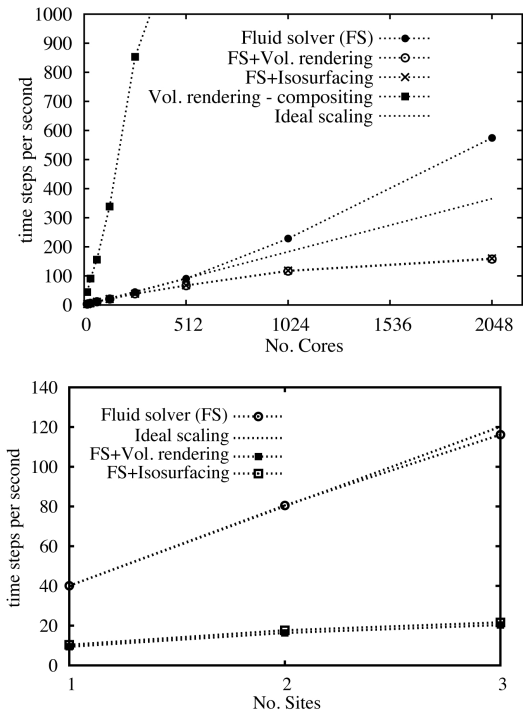

Figure 2: Code scaling across an increasing number of processors (top) and an increasing number of sites (bottom).

HemeLB is the lattice-Boltzmann (LB) solver at the core of the project that has been specifically designed to address fluid flow in sparse geometries such as the neurovasculature.

Rather than relying on post-processing visualization, an *in situ* volume rendering approach is used where the ray-traced domains correspond to the LB computational domains. Sub-images are composited to form a complete frame, and transmitted over the network to a lightweight client, resulting in immediate real-time visualization of the blood-flow simulation. The lightweight client allows a clinician to steer HemeLB using the RealityGrid steering library, where physical parameters of the vascular system along with various visualization properties can be adjusted in real-time. The scalability of the algorithm results in real-time rendering capabilities, even for high-resolution imaging datasets.

As a result we can now steer and visualize in real-time blood flow through patient-specific vasculatures within reservations on remote resources throughout the UK (NGS and NW-GRID) and USA (LONI and TeraGrid).

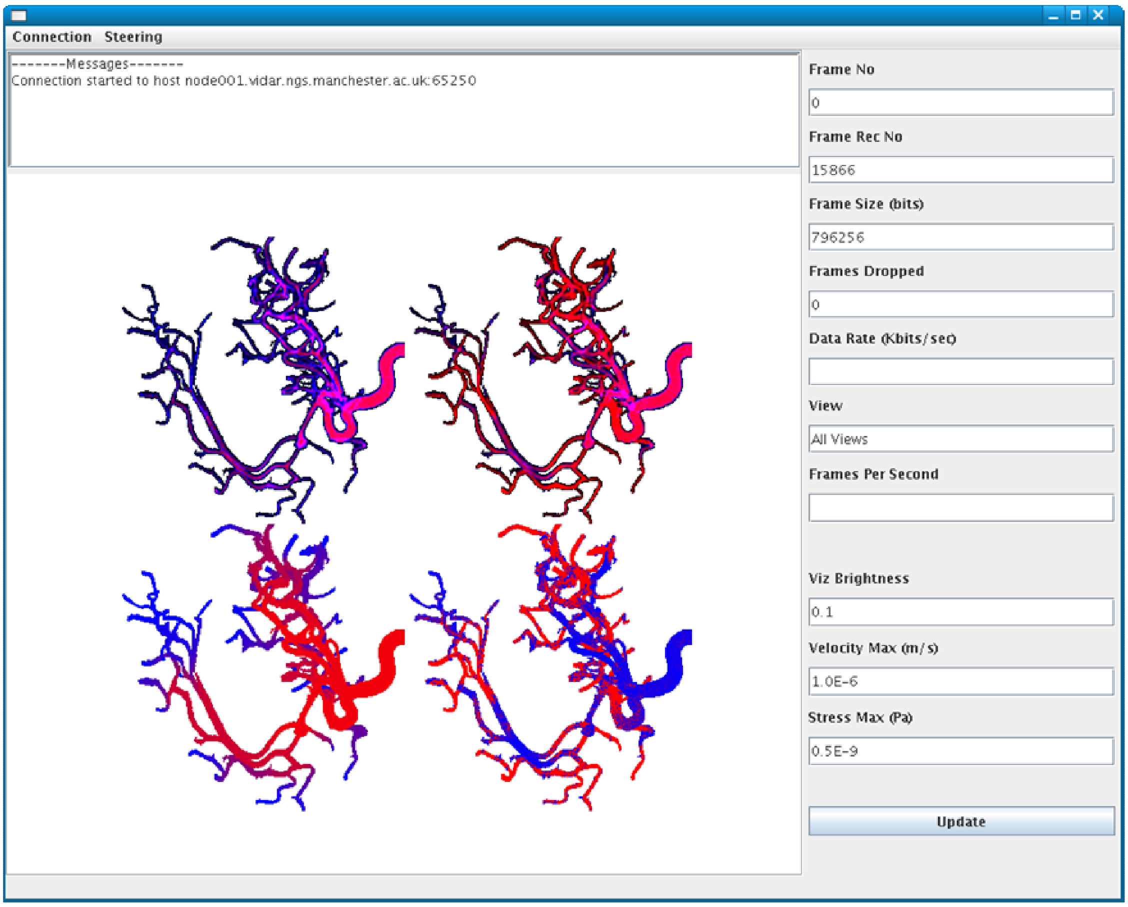

Figure 3: The GENIUS clinical user interface showing four different live visualizations of the neurovasculature and steering parameters.