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The Massive Scale Visualization and Simulation for Unstructured Hexahedron Mesh Data on TDW

Osaka University, Kyoto University and KGT Inc.

Background

Noise predictions combined with the computational fluid dynamics (CFD) method are growing popular, because advance of CFD enable the time series analyses of vortex. This improvements of simulation technologies enable engineers and scientists to explore the effective and theoretical design of not only industrial materials but also medical materials.

In our own body, there are growing expectations of the researching and developing the fundamental treatment methods of speech disorders, which are directly linked to Quality Of Life (QOL). In particular, the dental fricative voice has different characteristics of its sound production with the one of the vowel. The sound source of the dental fricative is downstream obstacle in the oral airflow field, where turbulence is dominant, although the vowel's sound source is the vibration of vocal cords by airflow thorough them. That is to say, frontal teeth are thought to be the obstacles against the turbulence and sound source so far. In oral therapies, the modification of oral morphological features is often happened on changing spatial positioning of jaws on the purpose of maxillofacial orthodontic therapies, prosthetic treatments of superstructures after dental implant surgeries and inserting sports mouthguards. Those alterations of oral morphologies may affect the characteristics of the resonance, and the magnitudes and region of the sound sources.

Therefore CFD and an acoustical simulation may predict the influence to the voice quality by such alteration of human oral geometries. To realize the prediction, huge amount of computational, storage and visualization resources are needed, which should be given in distributed environments. In order to understand the total view of oral air flow, the volumetric visualization are appropriate. As the oral air tract has very complicated morphological geometries, an unstructured mesh need to be taken and huge size of computational mesh are required to capture the vortex attitude. However, the volume rendering of unstructured mesh is not possible so far.

In this project, we've developed three components, the volume rendering software for massively huge data size complicated geometry data, middleware to achieve the data sharing, parallel processing and network monitoring, and an interactive human interface for visualization control in the design lab or etc.

Particle Based Volume Rendering

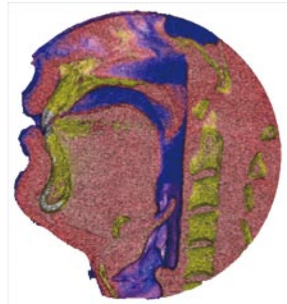
In this project, we will develop a system to visualize a large scale irregular volume dataset on a tiled display wall (TDW). The accomplishment of this project will be expected to become a visualization foundation for our national peta-scale computing facility which will be developed in 2011.The development of techniques for processing irregular volumes has remained a major challenge for the visualization community. Such datasets consist mainly of scalar data defined on collections of irregularly ordered cells whose shapes are not necessarily orthogonal cubic. In irregular volume rendering, one of the most major issues is to relax the processing requirement for the visibility sorting or to develop a technique without the sorting. To address the latter, we developed a particle-based volume rendering (PBVR) technique. In general, a volume rendering technique utilizes an illumination model in which the 3D scalar field is characterized as a varying density emitter with a single level of scattering. Our rendering technique represents the 3D scalar fields as a set of particles. The particle density is derived from a user-specified transfer function, and describes the number of particles in a unit volume at any given point.

Since the particles can be considered fully opaque, no visibility sorting processing is required during rendering process, and this is advantageous from a distributed processing perspective.

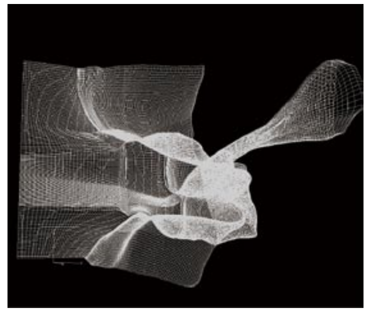
Currently, we confirmed that the technique can generate an image which is equivalent to the volume ray-casting's and deal with large irregular volume datasets in which the maximum number of tetrahedral cells exceeded one billion. In 2008, we will develop the remote visualization system in which a set of particles are transmitted through a high speed network. The next year, we will develop an integrated renderer which can process particles generated from geometric datasets such as polygons, polylines. In the final year, we will develop a streaming system which renders time-varying irregular volume datasets.

Interactive Human Interface

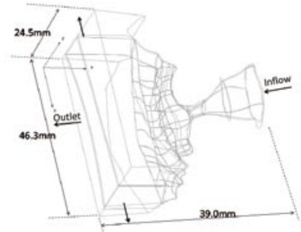
In this three-year project, the user interface team aims to develop a set of novel 3D interaction techniques for investigation and exploration of volumetric data. As opposed to a typical polygon-based virtual environment, interactive examination of volumetric data of interest exhibits a number of technical challenges to tackle; e.g. huge data size hinders its rendering at an interactive frame rate at the highest pixel resolution of the tiled display, self-occlusion prevents observation of an internal structure of interest. The user interface team will propose and validate new solutions to these problems by exploiting levels-of-detail techniques, interactive space-warping, multi-view rendering, and a diverse range of 3D interaction techniques.



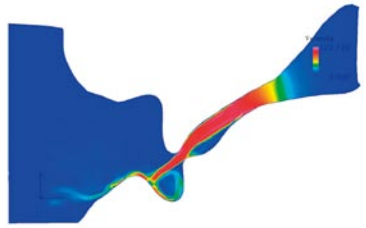
Human Vocal tract



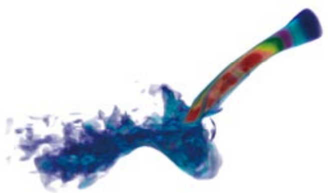
Unstructured Hexahedron Mesh



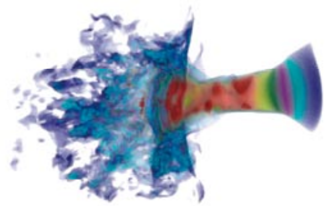
CFD Boundary Conditions



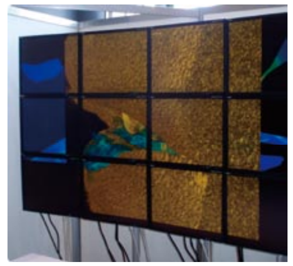
Conventional Visualization



PBVR for Velocity Field 1



PBVR for Velocity Field 2



Portable CMC TDW

Contact : Haruo Takemura,Director of CMC
E-mail : takemura@cmc.osaka-u.ac.jp