Visualizing Cetacean Auditory Responses to Underwater Noise

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LONG-TERM GOALS

The objective of this task is to create three-dimensional interactive simulations of sound propagation and impacts from both impulse and continuous sound sources. The visualizations will be driven by anatomical and simulation data provided by the Woods Hole Institute (WHOI) and BU (Boston University). This effort will extend prior research by using new visualization tools to model the both the auditory system, and the salient aspects of the skull and jaw involved in focusing incoming sound. The frames for rendered movies will be generated using finite element models. The NRL team will assemble the frames and create a three-dimensional movie linked to predictive models for the behavior of the auditory system. The movie can be displayed using an interactive three-dimensional display, as well as on a desktop workstation. During the second year of research, NRL will attempt to prototype a web-based implementation of the volume rendering techniques developed in year 1.

OBJECTIVES

In order to estimate the impact of anthropogenic noise sources on marine mammals, we must develop the ability to predict both physiological and behavioral responses of cetaceans to diverse acoustic sources. Behavioral experimentation is constrained by both technical and ethical considerations, but the detailed simulation of auditory processing provides a necessary alternative. To this end, our collaborators at WHOI and BU are attempting to develop biophysically-based models of the acoustic power flow from the water, through the tissues of the head and middle ear, and into the cochlea. These models will provide a basis for estimating the audiograms of species for which experimental data is otherwise unattainable, and for predicting the mechanical excitation pattern within the individual cochlea for a wide range of acoustic inputs. The purpose of the NRL task is to develop tools for visualizing the anatomical and simulation data generated by the WHOI and BU teams. The visualization tools will be used to model the auditory systems, and the salient aspects of the skull and jaw involved in focusing incoming sound.

APPROACH

Greg Schmidt, Virtual Reality Laboratory, NRL, is developing the software to visualize the scientific and medical data in NRL's 4-wall immersive room. The software engineering effort involves "stripping down" a software package (VBU Sea Visualizer [1]) utilized by another ONR project and re-engineering it to work with the current scientific and medical data. The initial steps are to obtain CT sections of a whale head, and develop a reader and display engine for the immersive room software. The display engine will support volumetric rendering methods. We will first utilize an iso-surface volumetric approach, which creates a volumetric model surface for each major tissue type in the medical data. The volume surfaces are not necessarily continuous, since there are separate body parts in some cases, and discontinuities associated with the resolution of the scanning of the data. The latter issue makes it difficult to create simple geometric models of the data. We will utilize the algorithm "Marching Cubes" developed by Lorensen and Cline [2] at GE Medical to construct the volume surfaces. The next step is a software engineering effort to develop an efficient display approach for the large volume surfaces that result.

WORK COMPLETED

This is a new start project for FY 04 with funds received in July 2004.

RESULTS

The results to date include:

1) Received a dataset of a whale head from Woods Hole in the form of CT sections.

2) Began the software engineering effort to develop a rendering engine that will show the medical data in the immersive room and desktop.

IMPACT/APPLICATIONS

This task will lead to an improved understanding of the impact of anthropogenic noise sources upon marine mammals. In particular, it will permit investigators to actually visualize the mechanical deformation of the cochlea in response to auditory over-stimulation.

RELATED PROJECTS

This effort builds upon a prior collaboration between NRL and WHOI conducted under the ONR ESME (Effects of Sound on the Marine Environment) program [3]. The task involved three-dimensional visualization of a complete dolphin head. NRL used a commercial product (3D-Doctor) to convert CT scans into 3D models after conversion from DICOM formats. The NRL researchers extracted the object boundaries and created 3D surface renderings to model the tissues and organs. These renderings were saved in a 3D model format and projected for viewing in the 4-wall immersive room.

REFERENCES

1. W. Lorensen and H. Cline. Marching Cubes: A High Resolution 3D Surface Construction Algorithm. *ACM Computer Graphics*, vol. 21, no. 24, pp. 163-169, July 1987.

2. G. Schmidt, S. Chen, A. Bryden, M. Livingston, B. Osborn, L. Rosenblum, "Multi-dimensional Visual Representations for Underwater Environmental Uncertainty", in submission to: IEEE *Computer Graphics & Applications*, Special Issue on Visual Analytics, Sep.-Oct. 2004.

3. Shyu, Haw-Jye, and R. Hillson, "A Software Workbench for Estimating the Effects of Cumulative Sound Exposure for Marine Mammals," accepted for publication in the IEEE *Journal of Oceanic Engineering*.