Project Summary

Understanding Unsteady Bioflows through Simulation, Modeling, Visualization, Art, and Psychology

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We propose a multi-disciplinary research project to discover new distributed simulation, visualization, and analysis tools for interacting with and understanding multi-valued volumes of scientific data and the biological phenomena they measure. The tools will be developed and evaluated in close collaboration with biologists studying three independent flow-related problems: coronary artery lesion and thrombus formation, the mechanisms and evolution of bat flight, and the mechanism and evolution of fish propulsion and maneuvering.

Intellectual Merit.

The proposed work addresses the National Priority Area of Advanced Science and Engineering (ASE) and several of the technical focus areas. It enables new forms of scientific research by developing new simulation capabilities (sim), integrating distributed experimental and simulation data (dmc+sim), and creating new human-computer interaction and visualization techniques for leveraging human intelligence (int).

The intellectual merit of the work includes advancing basic scientific understanding in the three biological application areas. In addition, the experimental methodology of acquiring 3D motion and flow data using 3D Digital Particle Image Velocimetry (DPIV) and high-speed video will advance the state of the art for studying flow interactions with other biological and man-made systems and may be used for prediction, risk-assessment and decision-making.

As we address these driving biological areas, we expect to discover solutions to some of the current hard problems in scientific visualization, including visualization of multi-dimensional time-varying multi-valued data, visualization of uncertainty, evaluation of the efficacy of visualization methods, and synthesis of visualization and computational modeling methods that are broadly applicable.

We will work to model expert visual designer knowledge, incorporating it into the quantitative evaluation process and building a system for automatically optimizing visualization methods based on such knowledge. We will also compare the effectiveness of visualization applications in several computing and displaying environments including a 4-wall Cave, a stereo display operating at the limit of human acuity, a 40'x40' virtual environment with a head mounted display, stereo-enabled desktop workstations with and without head-tracking, and standard desktop workstations. These characterizations will advance our knowledge about the kinds of interface hardware, user interface techniques, and visualization methods that will most effectively advance science and support reliable complex distributed systems.

The simulation and modeling work to address the biological problems will create new simulation methods for coupling unsteady flow and structure calculations, new methods for incorporating uncertainty into unsteady simulation results, new methods for combining unsteady experimental and simulation data to facilitate comparisons between them, and new methods for filling in gaps in unsteady experimental data.

Broader Impact.

Results from addressing these hard visualization problems for biological fluid flow applications are likely to generalize to other fluid applications, such as weather modeling and defense-related fluid simulations, as well as to other types of scientific data, such as medical imaging data. They have the potential to advance the pace of science and engineering (ASE) in many disciplines. These results may also apply beyond scientific applications by suggesting ways that visualization hardware and software can be most effectively used in many kinds of human-computer interaction.

Advances in the understanding of arterial flow have the potential to ultimately save lives and improve the quality of life for a significant portion of the population. An understanding of bat flight and fish propulsion mechanisms and evolution may go beyond the clear biological significance and direct us to more efficient and functional flying, floating, or submersible vehicles.

The collaborative aspects of this project may be useful quite broadly. Insight into collaborative research are could help make it more common. This work tightly integrates education and research. Students in all disciplines, including biologists, engineers, computer scientists, artists, designers, and perceptual psychologists will advance this interdisciplinary agenda as they develop their own careers, building a more diverse IT workforce.