Project Summary

Shape Capture and Modeling for Wrist Dynamics and Ancient Pottery Analysis using Manifold Surfaces and Signed-Distance Volume Images

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I propose research into shape modeling and its applications coupled with the development of a methodology for teaching the skills needed for successful multi-disciplinary research projects. The education plan is integrated with the research effort, which includes development of computational tools for capturing geometry, representing it within the computer, and using those representations for specific applications in archaeology and biological modeling.

The education plan consists of a course, *Interdisciplinary Scientific Visualization*, and a research group. Both welcome undergraduate and graduate students alike. The class mimics the research process, from choosing a project to presenting research results. Projects must include participants from multiple disciplines. During the semester students write a proposal, review proposals by others, work together on a project, write it up as a research abstract, review abstracts by others, and present their results. As the course progresses, lectures, readings, and discussion help to teach the art and craft behind each of those steps. The research group is derived from three research groups I participated in during my education: a primarily undergraduate group at Brown, a primarily graduate group at Caltech, and a second Caltech group that is primarily postdocs. The group combines aspects of all three to provide an environment that I believe will be conducive to learning how to do multi-disciplinary research at many levels.

The research that I propose is multi-disciplinary and fits well into the research group. Computational tools for capturing geometric shapes, representing them, and calculating with them will be developed and applied to problems from two disciplines: assembly of ancient pottery sherds in archaeology and modeling of wrist motion in orthopaedics and bioengineering. In both cases, shape will be captured from sampled volumetric CT medical imaging data. It will be represented implicitly using sampled signed-distance volumes and explicitly using manifold surfaces. The two representations compliment one another, together offering the strengths of both. For the archaeology application, we will develop a software architecture for decoupling the process of reasoning about artifact shapes from the understanding of their geometry. A probabilistic interface will separate the two parts. For the biological modeling application, we will develop models for bones, ligaments, and cartilage that will predict motion. We will validate the model with motion that we have already acquired and then use it to examine motion in patients with deficits that have thus far eluded an understanding.

The impact of this research will be in both application areas and the computational domain. If we are successful, pottery assembly, a process that is estimated to take over 50% of the time an excavation team spends outside of excavating, will be automated. We anticipate that this speedup will enable significant new archaeological results to emerge. A better understanding of the biomechanics of the arm and wrist and the abnormal conditions that can affect them could impact many Americans. This understanding will likely have applications in biology, bioengineering, medical applications, animation, and robotics. The numerical methods we will develop for simulating joints are likely to apply to simulations of other biological systems. Because the algorithms and tools for geometric modeling will be applied to two specific problems, they are likely to be more widely applicable.

Perhaps the most significant impact will be not in the scientific results, but in a better understanding of what makes multi-disciplinary research projects succeed or fail and in the new scientists that will emerge from Brown.