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Perspective article

Virtual anthropology meets biomechanics

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ABSTRACT

A meeting in Vienna in October 2010 brought together researchers using Virtual Anthropology (VA) and Finite Element Analysis (FEA) in order to explore the benefits and problems facing a collaboration between the two fields. FEA is used to test mechanical hypotheses in functional anatomy and VA complements and augments this process by virtue of its tools for acquiring data, for segmenting and preparing virtual specimens, and for generating reconstructions and artificial forms. This represents a critical methodological advance because geometry is one of the crucial inputs of FEA and is often the variable of interest in functional anatomy. However, we currently lack tools that quantitatively relate differences in geometry to differences in stress and strain, or that evaluate the impact on FEA of variation within and between biological samples. Thus, when comparing models of different geometry, we do not currently obtain sufficiently informative answers to questions such as "How different are these models, and in what manner are they different? Are they different in some anatomical regions but not others?" New methodologies must be developed in order to maximize the potential of FEA to address questions in comparative and evolutionary biology. In this paper we review these and other important issues that were raised during our Vienna meeting.

Finite Element Analysis (FEA) is a computer-based engineering technique that has been widely used in clinical biomechanics and is now being used as a tool in evolutionary biomechanics (see reviews in Richmond et al., (2005); Rayfield, (2007); Panagiotopoulou, (2009), Cobb, (2010); see also Curtis, (2010) for Multibody Modeling). Key steps for both areas of application include model creation (capturing geometry, assigning material properties, specifying simulated forces, and imposing constraints), model validation (entailing a comparison of FEA results with *in-vivo* or *in-vitro* experimental data), and virtual experimentation (altering the geometry or model parameters in order to inspect the biomechanical consequences of these changes). Regarding all three of these components, methods and tools that have been summarized as "Virtual Anthropology" (VA) (for more details see Weber and Bookstein (2011) or www.evan.at) can be of considerable help. While in the recent past many newly developed methods and tools in VA have been applied to humans and other primates, all of them can in principle be applied to any biological (or even non-biological) structure and indeed this has been the case. When we use the term "VA" (which is already in use in our discipline), it is meant as a synonym for these techniques (that include Geometric Morphometrics — GM), and we hope to address researchers from as many fields as possible with similar questions.

In October 2010, a two-day meeting in Vienna was organized by the European Virtual Anthropology Network Society (www.evan-society.org) to bring together researchers using VA and FEA and to teach software for form and shape analysis (the EVAN Toolbox). Participants of the "*Virtual Anthropology meets Biomechanics Workshop*" represented institutions from four continents and included anatomists, anthropologists, archeologists, behavioral scientists, bone biologists, engineers, paleontologists, statisticians, and dental morphologists. The goal of the meeting was to explore the problems facing a collaboration between VA and FEA, and the ways either of these approaches might benefit the other.

FEA can be used to examine how objects of complex geometry respond to external loads, and thus has the potential to test mechanical hypotheses in functional anatomy. However, clinical or evolutionary questions often cannot be answered from mechanics alone. For example, an evolutionary biologist might ask, "Does this aspect of skeletal morphology represent an adaptation to the performance of a particular behavior?" Mechanics may contribute to answering this question, but obviously only in a context that considers how the morphology of interest differs from other such forms or shapes. The geometry of the specimens being analyzed is crucial because it is one of the

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