Parametric Human Project Scope and Vision

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Abstract

The Parametric Human Project is an academic and industrial research consortium in Digital Human Modelling. The consortium will create an advanced data-driven biomechanical statistical anatomical model as a digital ergonomics and design tool to help users augment or accelerate human abilities. Applications may include education, surgery planning and simulation, biomechanics simulation, ergonomic design and implant design and simulation.

Keywords: digital human modeling, biomechanical ontology, anatomical variation, ergonomics, simulation.

1. Introduction

The Parametric Human Project (PHP) is an academic and industrial research consortium in Digital Human Modelling. The consortium will create an advanced data-driven biomechanical statistical anatomical model as a digital ergonomics and design tool to help users augment or accelerate human abilities. The PHP vision and mission is to create a complete morphological and physiological digital human model in order to greatly amplify the progress of the medical research community and the ergonomic design community through the systematic modelling of all human properties and processes.

We believe that three key problems have fundamentally restricted progress on understanding human properties and responses: a lack of direct community collaboration, a focus on animal-based research, and a lack of focus on a data-driven process. Due to the highly multi-disciplinary nature of our undertaking, sharing of data and algorithms between institutions will be critical to our success. However, this data must be strictly based on human anatomy and human tissue sources. Disparities between non-human animals and humans may “help to explain why the millions of dollars spent on basic research have yielded frustratingly few clinical advances.”[1] Furthermore, previous efforts have not taken a first-principles approach; a digital human model should begin with a human model. Yet, to date, a comprehensive anatomical ontology describing a complete morphological database has not been created. While the Visible Human Project [2] and the Virtual Physiological Human [3] are impressive related efforts, neither project has yet resulted in this type model. We hypothesize that the difficulties in creating a data-driven statistical human morphological model have prevented others from making progress in this area and this leads to mathematical modelling of abstract representations of idealized gross anatomy or sub-anatomic cellular modelling. Instead, we focus on geometric and ontological modelling in support of high-level biomechanical simulation. We emphasize the “parametric” aspect of humans to not just build a model of a specific human but to develop an understanding of human variation and co-variation of groups of morphological features. This common goal of the consortium is represented in our identity as a group (see Figure 1).

Figure 1. The logo of the Parametric Human Project represents the acronym together with the traditional icon for “Hospital” and drawn as a single ribbon to convey wholeness (design by Justin Matejka).

2. Human Information Model

A critical part of the Parametric Human Project will be the development of an advanced human anatomy ontology that captures anatomical variation and the varied tissue relationships involved. To achieve this, human ontology visualization, exploration, and authoring tools will be developed. In particular, extensible ontology development will be needed as additional features and relationships are discovered in both typical and pathological cases. The result should include statistical variation in the model as well as a model of the detailed geometric relationships found.

3. Systems

3.1 Human Skeletal System

The Human Skeletal System will be encoded through subprojects for Data Collection, Surface Meshing and Volume Registration, Landmarks, and Parameterization. Data Collection will require microCT scanning of samples, weighing and photographing, and high resolution point cloud surface scanning (see Figure 2). Surface Meshing starts from point cloud processing and detail-preserving meshing as well as controlled methods of reduction for lower levels-of-detail. Volume Registration of the microCT volumetric data to the mesh surfaces will result in simulation-ready digital bones as well as automated registration templates. Landmark annotation tools will support feature annotation by experts. Additionally, Computational Landmarks based on surface curvature and other geometric features will discover meaningful landmarks that are difficult for human determination. Feature-based correspondence and registration between samples will be attempted using constellation methods and related adjacency algorithms. Finally, Parameterization will analyze multiple samples for the automatic determination of machine and human-readable parameters of bone morphology. A reporting system of statistical variation of bone morphology will be developed to visualize and communicate salient aspects of the Parametric Skeleton.

3.2 Musculoskeletal System

The Human Musculoskeletal System adds additional challenges. This work can be grouped into subprojects for Data Collection, Meshing Volume, Landmarks, and Parameterization. Data collection will begin with full-body cadaveric MRI and CT scanning together with selected DT-MRI scans. This will be followed by the detailed digitization of the muscle fiber bundle architecture for all identifiable muscles (see Figure 2). Segmentation will be performed on both CT and MRI volume data into surface meshes to isolate anatomic components. Registration of fiber bundle data sets with corresponding MRI segmented meshes will be developed, followed by the generalization of the registration process to novel meshes to populate other muscle volumes with fiber architecture. Attempts will be made to validate the DT MRI scans against fiber data sets. Landmarks will be added as feature annotation by experts. Finally, the Parameterization will require the determination of the statistical variation of individual muscles as well as system of muscles.

4. Subject Breadth and Pathologies

Finally, an opportunity will exist to extend the scope of the project to include additional data sets on an ongoing basis to further strengthen the statistical findings for adult human subjects. Furthermore, the addition of growth models from immature to geriatric data sets would greatly enhance our understanding of human anatomy. Adding pathological data sets to potentially parameterize specific disorders could be critical in diagnosis and treatment.

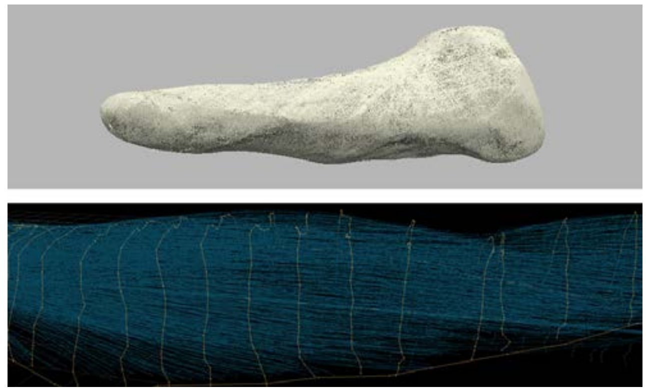

Figure 2. Exemplary data sets (software by Jacobo Bibliowicz). (Top) Distal Phalanx of the Thumb as represented by approximately 10 million points, digitized by Keith Hill. (Bottom) Extensor Forearm Compartment represented as thousands of muscle fiber bundle polylines, digitized by James Li and Anne Agur.

5. Conclusion

The Parametric Human Project officially began on February 1, 2012 as a research consortium founded by Azam Khan (Autodesk Research) with principal investigators Sidney Fels (University of British Columbia) and Anne Agur (University of Toronto) and great strides have been made in just twelve short months. The group has already grown and evolved, guided by our vision and mission, beyond Canada to international universities and government laboratories. Ultimately, we hope to enable numerous academic, industrial and government applications leveraging a complete human model to develop a broad variety of solutions to serve humanity.

References

[1] Bolker, J., “Model organisms: There's more to life than rats and flies,” Nature 491, 31; 2012.

[2] Visible Human Project, U.S. National Library of Health, National Institutes of Health, http://www.nlm.nih.gov/research/visible/visible_human.html.

[3] Virtual Physiological Human Network of Excellence (VPH NoE), http://www.vph-noe.eu/.