FEM Based Morphing of Whole Body Human Models

Dominik Szczerba, ***Esra Neufeld***, ***Marcel Zefferer***, ***Barbara Bühlmann***, and ***Niels Kuster***
IT'IS Foundation, ETH Zürich, Switzerland

Abstract

The requirements for virtual anatomical models are constantly growing due to the rapidly developing market for medical devices. It is important to provide optimal coverage of the potential population with anatomical models (with regard to height, pose, body mass index, etc.). The *Virtual Population* project already provides several "base" models, some of them poseable. In this study we demonstrate the applicability of the finite element method (FEM) to achieve realistic body poses and to predict changes in body appearance following volume increase or decrease of body fat parameterizing the body mass index (BMI) up to a factor of two.

1 Motivation

Virtual anatomical models are becoming increasingly popular in applications such as virtual exposure assessments or device compliance and safety testing that are required by national and international regulatory procedures. The requirements for such models are constantly growing due to the rapidly developing market for medical devices. It is important to provide optimal coverage of the potential population with anatomical models (with regard to height, pose, body mass index, muscle content, pregnancy stage, age, etc.). The *Virtual Population* models already provide multiple models (male/female, different age classes, children, obese, pregnant women), some of them poseable. In this study we aim to demonstrate the applicability of the finite element method to achieve realistic body poses and to predict changes in body appearance following volume increase or decrease of selected tissues (e.g. fat, muscle...), thus for the first time parameterizing the *Virtual Population* models.

2 Methods

While all the originally distinguished tissue types are preserved by the procedure, the FEM calculation needs only three major tissue types to be distinguished: rigid (bones), soft (organs, connective tissue, ...) and active (muscles, fat, ...). The changed anatomy following expansion, collapse or displacement of selected body regions is obtained from a quasi-static mechanical simulation with desired displacements or deforming forces prescribed as boundary conditions. The calculated deformation fields, possibly accounting for tissue anisotropies, are physically realistic and do not result from arbitrary geometrical warping. The approach works under the assumption of continuum and therefore requires high resolution of the input models.

3 Results

The procedure was employed to generate parametric BMI based models of one male and one female model at the resolution of 1mm voxel size. In addition, at similar resolution one adolescent model was posed by changing positions of arms and legs. The final models are represented by high quality multi-domain tetrahedron meshes, segmented images (voxels) as well as the original *Virtual Population* CAD format. Some manual retouching is needed to correct thin and small structures as there is some inherent progressive loss in the model geometrical fidelity (but not quality) due to discretization errors (smaller with higher resolution). The final model retains the differentiation of all the initially distinguished tissue types (about 100). The need to maintain the high resolution of the input models resulted in finite element meshes in the order of 100'000'000 elements and over a billion non-zero entries in the coefficient matrix. The necessary calculations required several hours on a dual hexacore system with 144 GB RAM.

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4 Conclusions

We have demonstrated the applicability of the finite element method for whole body posing or predicting anatomy changes following volume increase/decrease of selected tissues. Realistic results were obtained for BMI changes up to more than a factor of two. The presented procedure is robust, but consuming in terms of time and resources.

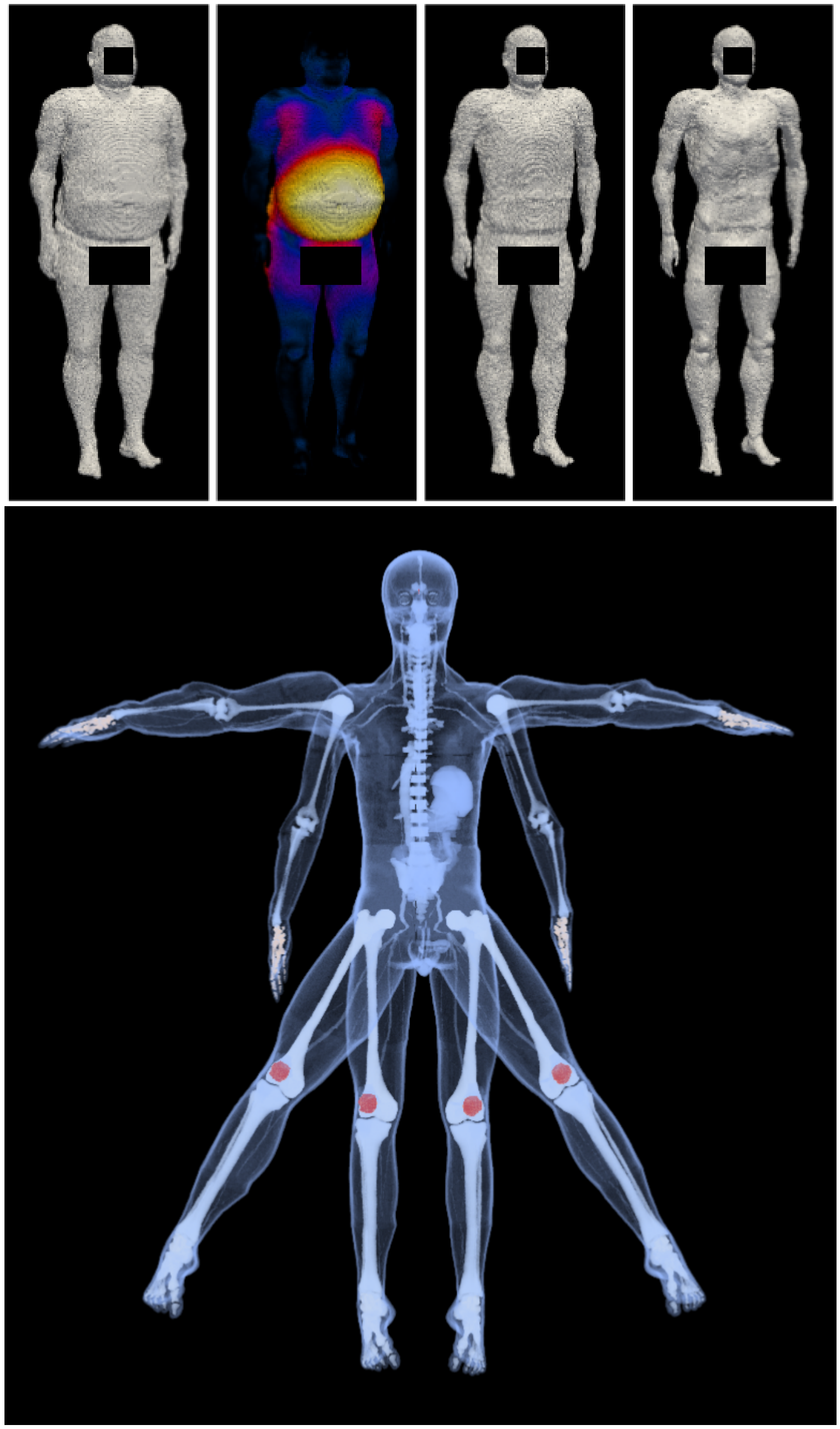

Figure 1: **Top:** Initial (0% fat loss), intermediate (50% fat loss) and final (100% fat loss) stages of a FEM based morphing along with a color-coded plot of of the deformation field. Note the triangular shape of the chest, the visible pelvis, ribs and sternum in the final stage. Note also, that the calves previously developed to support the excessive weight have not changed. **Bottom:** Initial and final stages of a simulation based posing of an adolescent model.