REALISTIC SKELETON BASED DEFORMATION OF HIGH-RESOLUTION

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INTRODUCTION

Several techniques are presented to improve skeleton-driven deformation of 3D skin models for visual purposes only. These techniques are extended and combined to efficiently accommodate high-resolution anatomical full-body models, including the deformation of all tissues and organs surrounding rigid bones. A visual system is also implemented to manipulate a hierarchical set of bones for simple and appropriate anatomical deformation modeling. It further allows the positioning of the underlying bone structure while considering user-defined joint constraints. The deformation is computed by providing immediate visual feedback to the user. The posed anatomical models are then applied to simulate exposure to and interaction with electromagnetic radiation.

METHODS

A tool has been developed and integrated into the existing electromagnetic simulation platform SEMCAD X to determine the influence regions of the bones. The user defines a set of bones as a hierarchical structure. Such a structure consists of a set of rigid bones connected with joints.

Every bone defines a volume of influence and a spatial weight distribution $w(x)$ (scalar field) attached to it.

The weight field $w(x)$ is defined as 1 inside the bones and within a certain user-defined layer on the bone surface, and it decreases smoothly to zero towards the boundary of the influencing volume. The tool allows the user to manipulate the influence volume such that it matches the bone and the tissues surrounding it. Since bones may have regions with overlapping influences, each vertex in the model is assigned a set of weights for every bone influence before performing the actual deformation.

Two methods have been implemented to perform the deformation:

- The resulting transformation of the vertex is computed using the Dual Quaternion Skinning method [3], which computes the interpolation of a set of rigid transformations in the dual quaternion space. This geometric approach allows the transition from one pose to another to be performed in one step. No iteration is necessary, thus allowing for interactive deformations of high-resolution models.

- A divergence-free vector field induced by the skeletal motion describing the velocity of the deformation is computed.

  This method, as described in [5], is volume-preserving and free of self-intersections due to a well-known property of divergence-free vector fields. Although this method is less interactive since it requires an iterative transition from one pose to another, it is more accurate. Every vertex of the model must be integrated along the path given by the divergence-free velocity vector field.

To ensure a more realistic deformation, the rigidity of the bone and its shape are considered through constraints on the weight field $w(x)$.

The hierarchy of linked bones allows the propagation of transformations through a whole limb if the user moves the parent bone. The Inverse Kinematics problem is also solved to achieve a desired pose of the bone structure while satisfying the defined joint

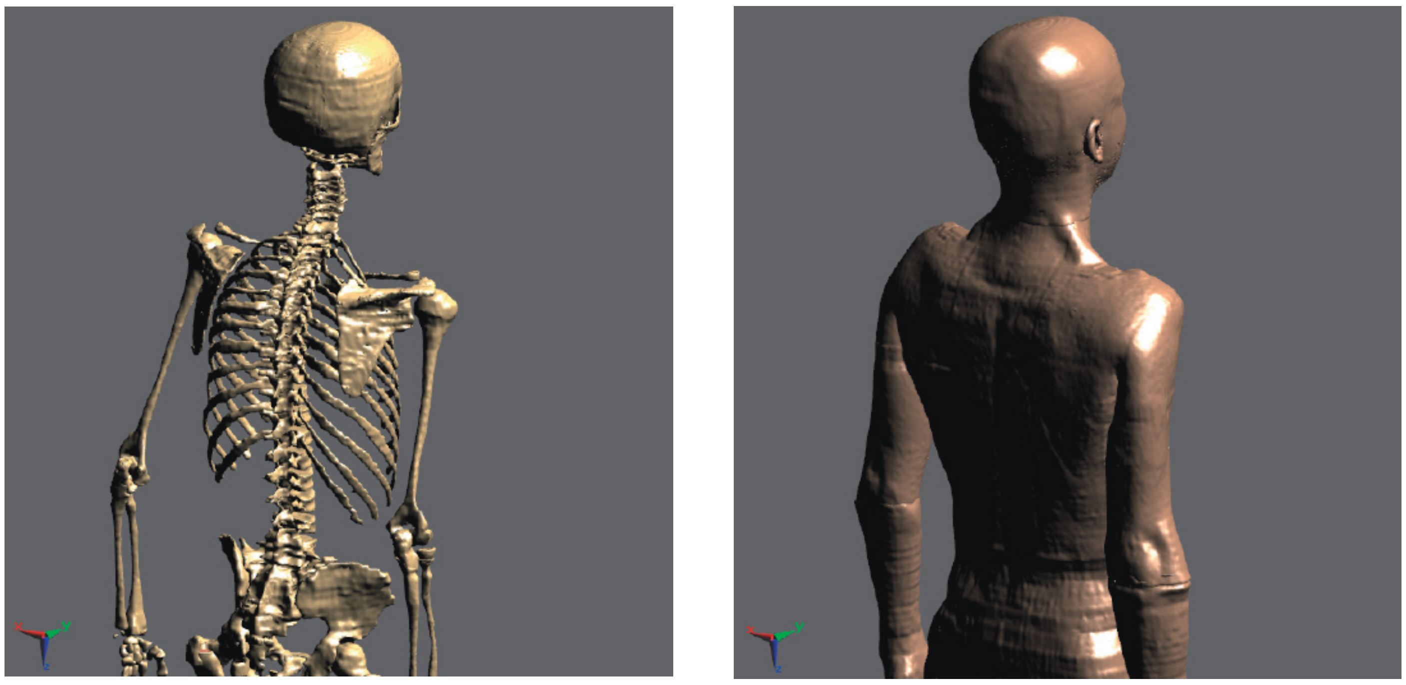

Figure 1a: Original pose of a whole-body model from the Virtual Family Project

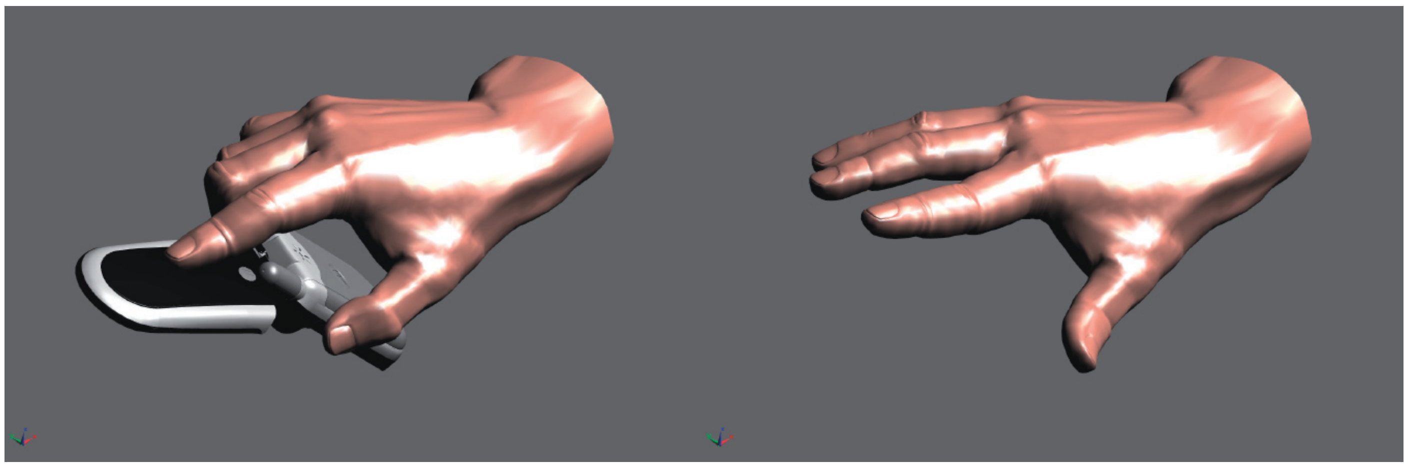

Figure 3: Original pose of a hand model, and pose of a hand holding a mobile phone

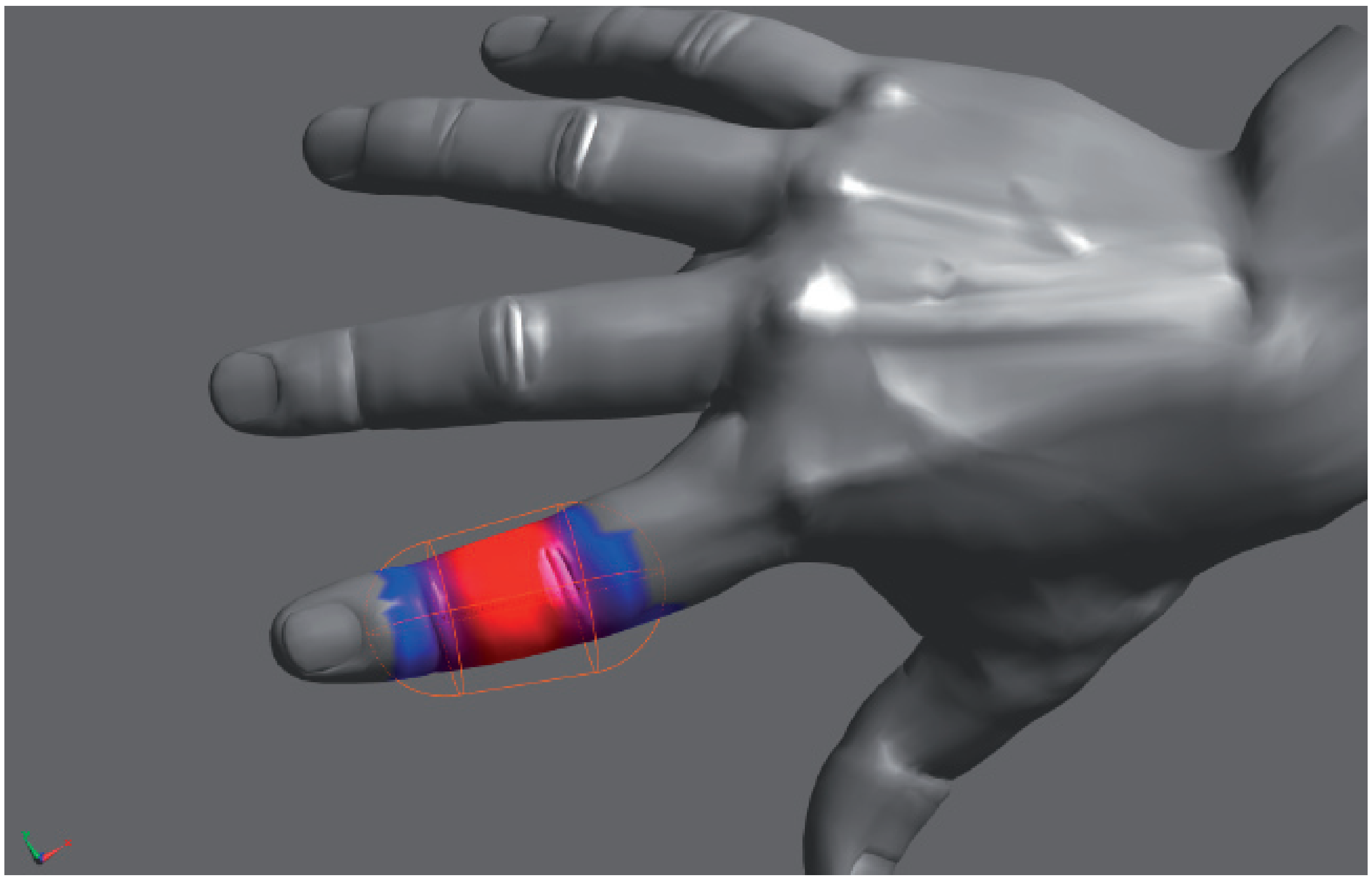

Figure 2: The influence weight distribution w(x) and its volume of influence is shown for a single bone in a hand

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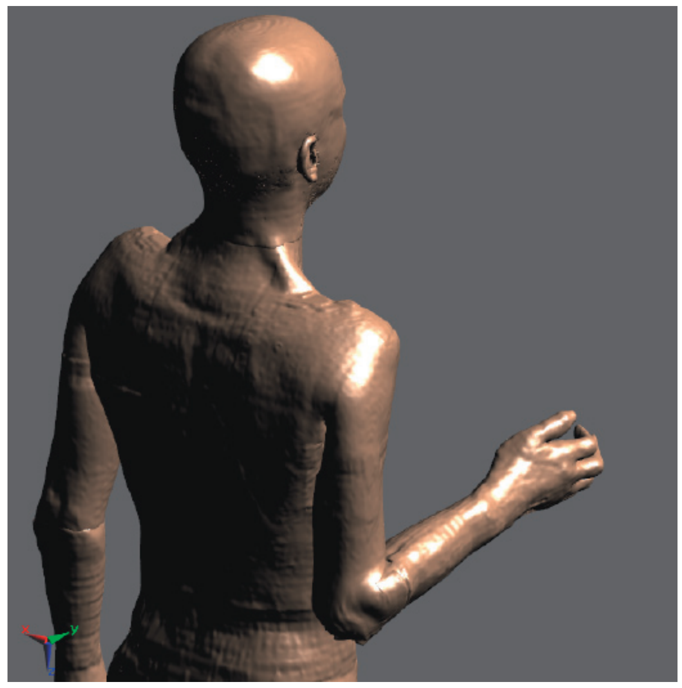

Figure 1b: Changed pose of the model shown in 1a

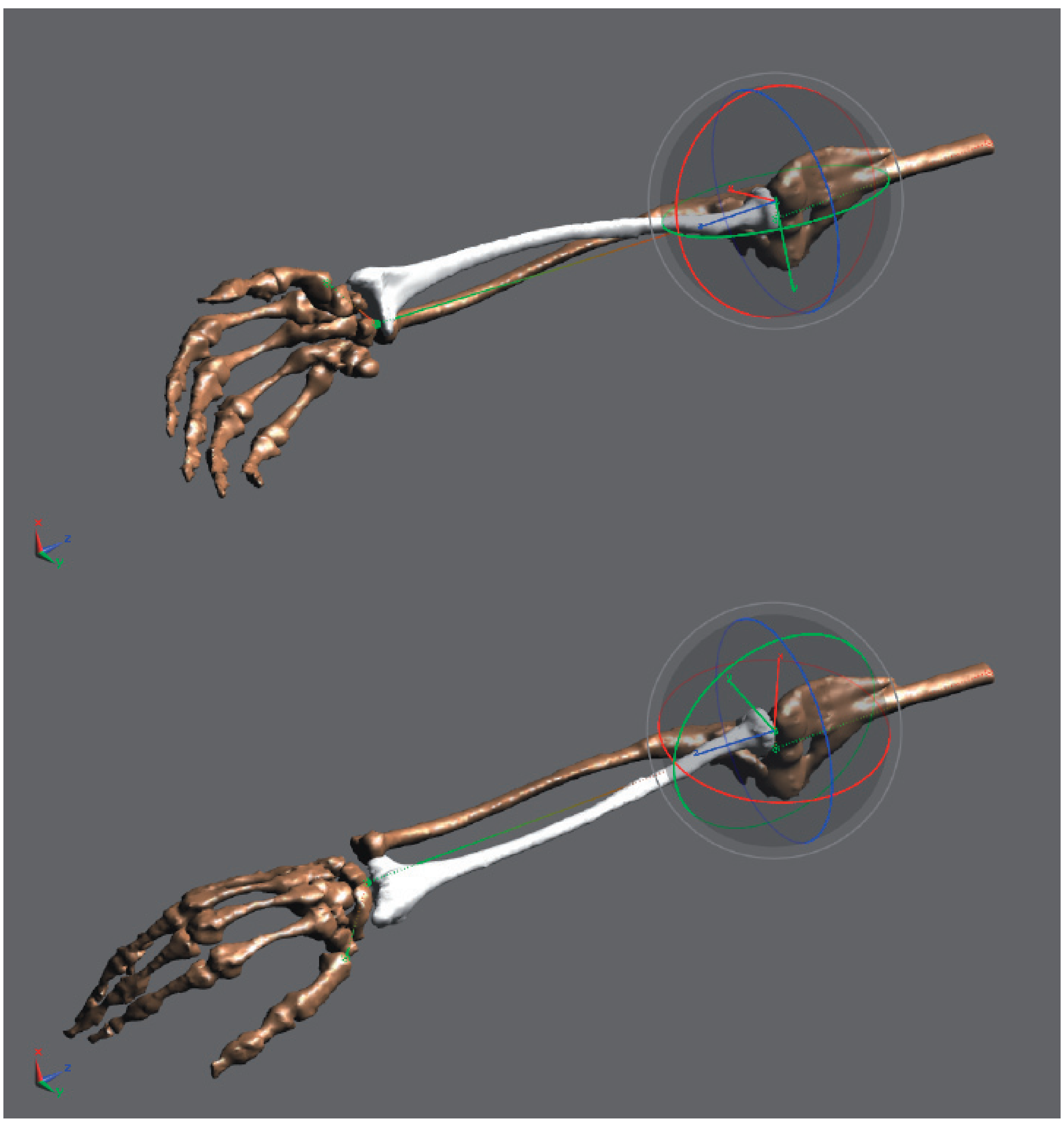

Figure 4: Interactive simulation of a complex bone system such as the Ulna and Radius bones with pre-defined constraints on the joints is shown

constraints. A non-iterative method based on Lagrange multipliers, as described in [1], is applied to simulate the articulation of the bone system, which provides a fast and intuitive way to define a posture by simply rotating the bone joints to the desired target location.

IMPLEMENTATION

All the methods described here have been implemented and integrated into the simulation software package SEMCAD X. Models with millions of triangles were imported and posed, e.g. high-resolution anatomical human whole-body models from the Virtual Family project [4]. Although much effort was dedicated to setting up the bone influence regions on the user interface, further revisions are necessary with respect to the influence volumes, especially at complex joints such as the hand bones or the whole torso.
To achieve better performance on multi-processor and multi-core systems, the implementation of the deformation is parallelized. The mesh undergoing deformation is subdivided into chunks and their deformation procedures distributed to various threads.

CONCLUSIONS

The implemented poser based on techniques developed for animation pictures features:

- easy to articulation of joints in their physiological ranges
- deformation of the soft tissue without loss of connectivity and without changes in the total tissue volume
- predefined postures for standing, sitting and lying persons
- compatibility with all of our 3D CAD human models as well as selected rodents

This poser combined with the most detailed human models will transform exposure evaluations in real situations, such as work places, and device optimization, e.g., hand-held devices, body-mounted or implantable devices, to a new level of sophistication.

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