Sensorimotor Physiology: Modeling, Imaging, and Neural Control

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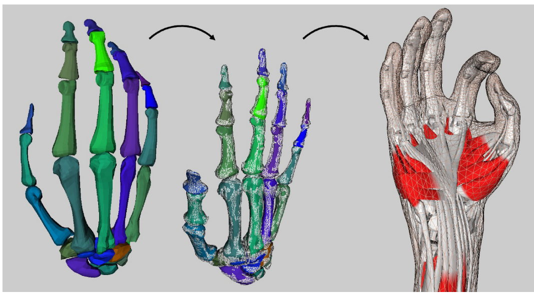

Figure 1: *Animatable model of hand. Arm template with muscles and bones acquired from MRI. Can be registered to MRI images and skeleton in different postures.*

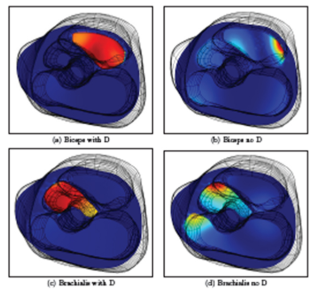

Figure 2: *Computed myography (CMG) of the upper arm reveals muscle activity during movement.*

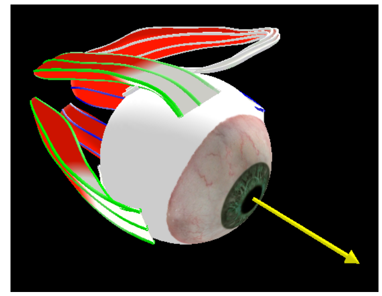

Figure 3: *Simulation of eye movement. Extraocular muscle shapes measured with MRI and fitted with multiple muscle strands.*

Based on recent developments in computer simulation, medical imaging, and neurophysiology, we can now construct detailed functional models of the human biomechanical plant, its neural control, and its physical interaction with the environment. These new developments will have a profound impact on both how computer animation will be done in the future and how we understand human movement in science and medicine.

This approach could lay a new foundation for computer animation of human-like characters based on simulation of human physiology and neural control. It will allow human character animation to be specified at a much higher level and will automatically reproduce important features such as the visible movement of muscles, tissue deformation on contact, and dynamic constraints.

Conversely, these developments could lead to a deeper, more constructive understanding of human movement. The human body and brain are among the most complex systems studied in science. They will place enormous new demands on computer graphics to simulate these complex systems efficiently (preferably at interactive rates) and to visualize complex behaviors. There are many applications in medicine, including diagnosis of residual hand function following spinal cord injury, stroke, or repetitive stress injuries; surgical planning and rehabilitation; and control of neuroprosthetics.

We will describe ongoing work in our group for constructing such models of the musculoskeletal system, using fiber-like 3D elastic elements we call "strands" [Sueda et al. 2008]. We will also describe how these models can be constructed using many imaging techniques, including MRI (Magnetic Resonance Imaging) [Gilles and Pai 2008], DTI (Diffusion Tensor Imaging), CMG (Computed Myography, which estimates activity of muscles)[van den Doel et al. 2008], and CT (Computed Tomography). We will provide examples of modeling the human hand and eye [Wei et al. 2010], and animals including frogs and rats. Taken together, these techniques demonstrate a new constructive approach to understanding biological sensing and motor control.

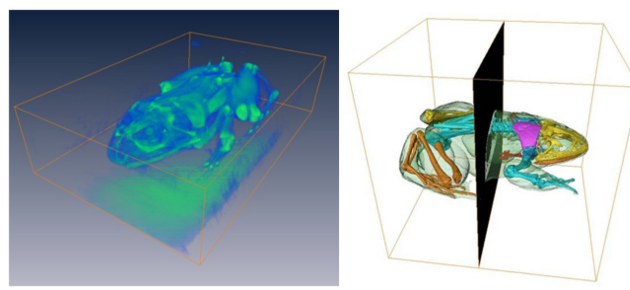

Figure 4: *Three dimensional model of frog acquired from high resolution micro CT images (left), producing an animatable skeleton and skin (right).*

References

Gilles, B., and Pai, D. K. 2008. Fast musculoskeletal registration based on shape matching. In *Proceedings of Medical Image Computing and Computer-Assisted Intervention - MICCAI 2008*, LNCS 5242 Part II, 822–827.

Sueda, S., Kaufman, A., and Pai, D. K. 2008. Musculotendon simulation for hand animation. *ACM Trans. Graph. (Proc. SIGGRAPH) 27*, 3, 83:1–83:8.

van den Doel, K., Ascher, U. M., and Pai, D. K. 2008. Computed myography: three dimensional reconstruction of motor functions from surface emg data. *Inverse Problems 24*, 065010, 17 pages.

Wei, Q., Sueda, S., and Pai, D. K. 2010. Biomechanical simulation of human eye movement. In *Proceedings of the International Symposium on Biomedical Simulation (ISBMS10)*, 108–118.

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