# Capturing and Animating Skin Deformation in Human Motion

Sang Il Park*　　Jessica K. Hodgins†

School of Computer Science
Carnegie Mellon University

Figure 1: Capture and animation of the dynamic motion of the surface of the human body.

## Abstract

During dynamic activities, the surface of the human body moves in many subtle but visually significant ways: bending, bulging, jiggling, and stretching. We present a technique for capturing and animating those motions using a commercial motion capture system and approximately 350 markers. Although the number of markers is significantly larger than that used in conventional motion capture, it is only a sparse representation of the true shape of the body. We supplement this sparse sample with a detailed, actor-specific surface model. The motion of the skin can then be computed by segmenting the markers into the motion of a set of rigid parts and a residual deformation (approximated first as a quadratic transformation and then with radial basis functions). We demonstrate the power of this approach by capturing flexing muscles, high frequency motions, and abrupt decelerations on several actors. We compare these results both to conventional motion capture and skinning and to synchronized video of the actors.

**CR Categories:** I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation

**Keywords:** human animation, motion capture, skin deformation

## 1 Introduction

Optical motion capture has been used very successfully to create compelling human animations for movies and sports video games; however, it provides only a much simplified version of what we would see if we were to view a person actually performing those actions. The data contain an approximation of the motion of the skeleton but miss such subtle effects as the bulging of muscles and the jiggling of flesh. The current state of the art for whole body capture uses a set of 40-60 markers and reduces it to the rigid body motion of 15-22 segments. To the extent possible, the markers are placed on joint axes and bony landmarks so that they can more easily be used to approximate the motion of the skeleton. Biomechanical invariants are often used to reduce the number of markers to less than the number required to fully specify the orientation of each limb.

In this paper, we take a different approach to motion capture and use a very large set of markers (approximately 350) placed not on bony landmarks but on the muscular and fleshy parts of the body. Our goal is to obtain not only the motion of the skeleton but also the motion of the surface of the skin.

We accurately reconstruct the motion of the surface of the body by applying the three-dimensional trajectories for this dense marker set to a subject-specific polygonal model (Figure 1). The polygonal model is first optimized to fit the three-dimensional locations of the markers from a static pose. During the motion, the rigid body motion of the dense marker set is extracted and the remaining motion of the markers is used to compute local deformations of the polygonal model. The position of occluded markers is estimated from the locations of neighboring markers using a local model of the surface shape. The deformations of the marker set allow the muscle shapes in the polygonal model to grow and shrink and the fleshy areas to move dynamically.

To demonstrate the viability of this technique, we captured the motion of two subjects: a male football player (university-level offensive lineman) and a female professional belly dancer. Both subjects exhibited significant muscle and skin deformation when they performed dynamic activities. To evaluate the results, we compared motion captured with the dense marker set to synchronized video and to similar motions captured with a standard marker set and rendered using the same model and the skinning techniques available in commercial software.

*e-mail: sipark@cs.cmu.edu
†e-mail: jkh@cmu.edu



## 2 Background

Data-driven approaches such as the one described in this paper are only one possible way to create an animation of the deformations

LEWIS, J. P., CORDNER, M., AND FONG, N. 2000. Pose space deformations: A unified approach to shape interpolation and skeleton-driven deformation. In *Proceedings of ACM SIGGRAPH 2000*, Computer Graphics Proceedings, Annual Conference Series, 165–172.

LIN, I.-C., AND OUHYOUNG, M. 2005. Mirror mocap: Automatic and efficient capture of dense 3d facial motion parameters from video. *The Visual Computer 21*, 6, 355–372.

LIN, I.-C., YENG, J.-S., AND OUHYOUNG, M. 2002. Extracting 3d facial animation parameters from multiview video clips. *IEEE Computer Graphics & Applications 22*, 6, 72–80.

LIPMAN, Y., SORKINE, O., LEVIN, D., AND COHEN-OR, D. 2005. Linear rotation-invariant coordinates for meshes. *ACM Transactions on Graphics 24*, 3, 479–487.

MAGNENAT-THALMANN, N., AND THALMANN, D. 2005. Virtual humans: thirty years of research, what next? *The Visual Computer 21*, 12, 997–1015.

MOHR, A., AND GLEICHER, M. 2003. Building efficient, accurate character skins from examples. *ACM Transactions on Graphics 22*, 3, 562–568.

MÜLLER, M., HEIDELBERGER, B., TESCHNER, M., AND GROSS, M. 2005. Meshless deformations based on shape matching. *ACM Transactions on Graphics 24*, 3, 471–478.

NEDEL, L. P., AND THALMANN, D. 2000. Anatomic modeling of deformable human bodies. *The Visual Computer 16*, 6, 306–321.

PRATSCHER, M., COLEMAN, P., LASZLO, J., AND SINGH, K. 2005. Outside-in anatomy based character rigging. In *2005 ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 329–338.

PRONOST, N., DUMONT, G., BERILLON, G., AND NICOLAS, G. 2006. Morphological and stance interpolations in database for simulating bipedalism of virtual humans. *The Visual Computer 22*, 1, 4–13.

SAND, P., MCMILLAN, L., AND POPOVIĆ, J. 2003. Continuous capture of skin deformation. *ACM Transactions on Graphics 22*, 3, 578–586.

SCHEEPERS, F., PARENT, R. E., CARLSON, W. E., AND MAY, S. F. 1997. Anatomy-based modeling of the human musculature. In *Proceedings of SIGGRAPH 97*, Computer Graphics Proceedings, Annual Conference Series, 163–172.

SEO, H., AND MAGNENAT-THALMANN, N. 2003. An automatic modeling of human bodies from sizing parameters. In *2003 ACM Symposium on Interactive 3D Graphics*, 19–26.

SEO, H., CORDIER, F., AND MAGNENAT-THALMANN, N. 2003. Synthesizing animatable body models with parameterized shape modifications. In *2003 ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 120–125.

SHUM, H.-Y., IKEUCHI, K., AND REDDY, R. 1995. Principal component analysis with missing data and its application to polyhedral object modeling. *IEEE Transactions on Pattern Analysis and Machine Intelligence 17*, 9, 854–867.

SIFAKIS, E., NEVEROV, I., AND FEDKIW, R. 2005. Automatic determination of facial muscle activations from sparse motion capture marker data. *ACM Transactions on Graphics 24*, 3, 417–425.

SINGH, K., AND KOKKEVIS, E. 2000. Skinning characters using surface oriented free-form deformations. In *Graphics Interface*, 35–42.

SLOAN, P.-P. J., III, C. F. R., AND COHEN, M. F. 2001. Shape by example. In *2001 ACM Symposium on Interactive 3D Graphics*, 135–144.

SUMNER, R. W., ZWICKER, M., GOTSMAN, C., AND POPOVIĆ, J. 2005. Mesh-based inverse kinematics. *ACM Transactions on Graphics 24*, 3, 488–495.

SUN, W., HILTON, A., SMITH, R., AND ILLINGWORTH, J. 2001. Layered animation of captured data. *The Visual Computer 17*, 8, 457–474.

TERAN, J., SIFAKIS, E., BLEMKER, S. S., NG-THOW-HING, V., LAU, C., AND FEDKIW, R. 2005. Creating and simulating skeletal muscle from the visible human data set. *IEEE Transactions on Visualization and Computer Graphics 11*, 3, 317–328.

TERAN, J., SIFAKIS, E., IRVING, G., AND FEDKIW, R. 2005. Robust quasistatic finite elements and flesh simulation. In *2005 ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 181–190.

VICON MOTION SYSTEMS, 2006. http://www.vicon.com/.

VLASIC, D., BRAND, M., PFISTER, H., AND POPOVIĆ, J. 2005. Face transfer with multilinear models. *ACM Transactions on Graphics 24*, 3, 426–433.

WALLRAVEN, C., BREIDT, M., CUNNINGHAM, D. W., AND BÜLTHOFF, H. H. 2005. Psychophysical evaluation of animated facial expressions. In *APGV 2005*, 17–24.

WANG, X. C., AND PHILLIPS, C. 2002. Multi-weight enveloping: Least-squares approximation techniques for skin animation. In *ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 129–138.

WANG, Y., HUANG, X., LEE, C.-S., ZHANG, S., LI, Z., SAMARAS, D., METAXAS, D., ELGAMMAL, A., AND HUANG, P. 2004. High resolution acquisition, learning and transfer of dynamic 3-d facial expressions. *Computer Graphics Forum 23*, 3, 677–686.

WILHELMS, J., AND GELDER, A. V. 1997. Anatomically based modeling. In *Proceedings of SIGGRAPH 97*, Computer Graphics Proceedings, Annual Conference Series, 173–180.

ZALEWSKI, L., AND GONG, S. 2005. 2d statistical models of facial expressions for realistic 3d avatar animation. In *CVPR*, 217–222.

ZHANG, L., SNAVELY, N., CURLESS, B., AND SEITZ, S. M. 2004. Spacetime faces: high resolution capture for modeling and animation. *ACM Transactions on Graphics 23*, 3, 548–558.

ZORDAN, V. B., AND HORST, N. C. V. D. 2003. Mapping optical motion capture data to skeletal motion using a physical model. In *2003 ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 245–250.

ZORDAN, V. B., CELLY, B., CHIU, B., AND DILORENZO, P. C. 2004. Breathe easy: model and control of simulated respiration for animation. In *2004 ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, 29–37.