Reference List 15-464 / 15-664 Feb 6, 2019

We started by looking at a couple of motion editing papers from recent years.

Kapadia, Mubbasir, Xu Xianghao, Maurizio Nitti, Marcelo Kallmann, Stelian Coros, Robert W. Sumner, and Markus Gross. "Precision: Precomputing environment semantics for contact-rich character animation." In *Proceedings of the 20th ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, pp. 29-37. ACM, 2016.
https://www.disneyresearch.com/publication/contact-rich-character-animation/

Koyama, Yuki, and Masataka Goto. "OptiMo: Optimization-Guided Motion Editing for Keyframe Character Animation." In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, p. 161. ACM, 2018.
https://koyama.xyz/project/optimo/

The we turned to the main topic of skinning.
This SIGGRAPH 2014 course contains a great deal of useful information

Alec Jacobson, Zhigang Deng, Ladislav Kavan, J. P. Lewis.
Skinning: Real-time Shape Deformation
SIGGRAPH Course, 2014.

The fastest skinning computations are direct techniques. Linear blend skinning (LBS) and its problems are described in the first section of the SIGGRAPH course notes. In particular, there is a nice description of the candy wrapper effect.

Pinocchio uses LBS with good results. Code is available and you can try it out.

Baran, Ilya, and Jovan Popović. "Automatic rigging and animation of 3d characters." In *ACM Transactions on Graphics (TOG)*, vol. 26, no. 3, p. 72. ACM, 2007.
http://www.mit.edu/~ibaran/autorig/

Much research, however, has focused on maintaining the speed and ease of use of LBS and removing the artifacts. We talked about this paper, which uses dual quaternion blending to remove twisting artifacts

Kavan, Ladislav, Steven Collins, Jiří Žára, and Carol O'Sullivan. "Geometric skinning with approximate dual quaternion blending." *ACM Transactions on Graphics (TOG)* 27, no. 4 (2008): 105.
http://dl.acm.org/citation.cfm?id=1409627
https://www.youtube.com/watch?v=LUOJccOZfWQ

.. and this paper introducing the idea of differential blending (breaking up large rotations into collections of small ones), which works well even for very large twists and deformations, such as might be needed for cartoon effects.

Öztireli, A. Cengiz, Ilya Baran, Tiberiu Popa, Boris Dalstein, Robert W. Sumner, and Markus Gross. "Differential blending for expressive sketch-based posing." In *Proceedings of the 12th ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, pp. 155-164. ACM, 2013.
https://graphics.ethz.ch/publications/papers/paperOzt13.php

An alternative to LBS or dual quaternions is to use cages. Cages are a very old idea dating back to early (vector!) graphics

Burtnyk, Nester, and Marceli Wein. "Interactive skeleton techniques for enhancing motion dynamics in key frame animation." *Communications of the ACM* 19, no. 10 (1976): 564-569.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.151.8234&rep=rep1&type=pdf

The technique developed in this 1976 paper was used in the movie Hunger by Peter Foldes
https://www.nfb.ca/film/hunger

Here is a more modern paper showing some of the effects that can be sculpted using the cage based approach

Ju, Tao, Qian-Yi Zhou, Michiel van de Panne, Daniel Cohen-Or, and Ulrich Neumann. "Reusable skinning templates using cage-based deformations." In *ACM Transactions on Graphics (TOG)*, vol. 27, no. 5, p. 122. ACM, 2008.
https://dl.acm.org/citation.cfm?id=1409075
https://www.youtube.com/watch?v=tPdsh6VclEg

We then discussed how using implicit functions to describe body parts such that the location of the skin is defined by a distance function placed around body segments. Here are two papers on this topic. The second one makes use of particle based physics to give the internal muscle structure some dynamics and collision avoidance.

Vaillant, Rodolphe, Gäel Guennebaud, Loïc Barthe, Brian Wyvill, and Marie-Paule Cani. "Robust iso-surface tracking for interactive character skinning." *ACM Transactions on Graphics (TOG)* 33, no. 6 (2014): 189.
https://dl.acm.org/citation.cfm?id=2661264
https://www.youtube.com/watch?v=GyOwwNvHA1w

Roussellet, Valentin, Nadine Abu Rumman, Florian Canezin, Nicolas Mellado, Ladislav Kavan, and Loïc Barthe. "Dynamic implicit muscles for character skinning." *Computers & Graphics* 77 (2018): 227-239.
https://www.sciencedirect.com/science/article/pii/S0097849318301742
https://www.youtube.com/watch?v=aYYG7uBtaNY

We then moved to example based techniques, as in this 2000 SIGGRAPH paper on Pose Space Deformation. The challenge is to find interpolation techniques that work well for sparse examples in high dimensional spaces

Lewis, John P., Matt Cordner, and Nickson Fong. "Pose space deformation: a unified approach to shape interpolation and skeleton-driven deformation." In *SIGGRAPH 2000.*
http://dl.acm.org/citation.cfm?id=344862
https://www.youtube.com/watch?v=XPxRftplwJM

The Pose Space Deformation approach was used in the film Bolt, as discussed in this short article:
http://disney-animation.s3.amazonaws.com/library/poseSpaceDef.pdf

Finally, we turned to rigs. This paper discusses simulations of equations of motion in the rig space of a character in order to fit simulation into the traditional artist pipeline.

Hahn, Fabian, Sebastian Martin, Bernhard Thomaszewski, Robert Sumner, Stelian Coros, and Markus Gross. "Rig-space physics." *ACM transactions on graphics (TOG)* 31, no. 4 (2012): 72.
https://dl.acm.org/citation.cfm?id=2185568
https://www.youtube.com/watch?v=8XuwqGdkEWE

Computing rig transformations can be arbitrarily complex and may not be suitable for real-time computation. The following paper describes a deep learning approach to learning the nonlinear portions of the rig transformations.

Bailey, Stephen W., Dave Otte, Paul Dilorenzo, and James F. O'Brien. "Fast and deep deformation approximations." *ACM Transactions on Graphics (TOG)* 37, no. 4 (2018): 119. http://graphics.berkeley.edu/papers/Bailey-FDD-2018-08/index.html