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The focus of attention today was on the following paper:

Liu, Lijuan, Youyi Zheng, Di Tang, Yi Yuan, Changjie Fan, and Kun Zhou. "Neuroskinning: Automatic skin binding for production characters with deep graph networks." ACM Transactions on Graphics (TOG) 38, no. 4 (2019): 1-12.
https://dl.acm.org/doi/abs/10.1145/3306346.3322969
http://kunzhou.net/

Digging into the introduction, we first had a look at direct methods for skinning, which are widely used in production, specifically Linear Blend Skinning (LBS) and Dual Quaternion Skinning (DQS). As resources to discuss these techniques, I used the following papers:

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.

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.

Much research 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

If you are interested in learning more about dual quaternions, this paper is one of many overview / tutorials which explain the idea:

Leclercq, Guillaume, Philippe Lefèvre, and Gunnar Blohm. "3D kinematics using dual quaternions: theory and applications in neuroscience." Frontiers in behavioral neuroscience 7 (2013): 7.
https://www.frontiersin.org/journals/behavioral-neuroscience

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

As the Neuroskinning paper mentions, one difficulty with direct methods such as LBS and DQS is that they require an artist to paint weights on a model to assign vertices to bones. Many methods have been developed to automatically assign weights, although all have their difficulties. We looked at Pinocchio, which uses a heat transfer technique to automatically "paint" weights onto a character mesh. Interestingly, 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.
https://dl.acm.org/doi/abs/10.1145/1276377.1276467

Digging further into related research on skinning (referring back to the Neuroskinning paper), we see that skinning research can be divided into three categories: physics based, example based, and geometry based. Geometry based are just the direct methods we have seen already, such as LBS and DQS.

Here are two examples of physics based approaches that we saw in class. Physics based approaches are designed to capture effects such as skin jiggle that result from dynamic motions and impacts that cannot be captured from static pose alone.

Kim, Meekyoung, Gerard Pons-Moll, Sergi Pujades, Seungbae Bang, Jinwook Kim, Michael J. Black, and Sung-Hee Lee. "Data-driven physics for human soft tissue animation." ACM Transactions on Graphics (TOG) 36, no. 4 (2017): 1-12.
https://ps.is.tuebingen.mpg.de/publications/meekyoung-siggraph

Mukai, Tomohiko, and Shigeru Kuriyama. "Efficient dynamic skinning with low-rank helper bone controllers." ACM Transactions on Graphics (TOG) 35, no. 4 (2016): 1-11. https://mukai-lab.org/publications/siggraph2016/

Here are two papers that use example-based techniques. Example based techniques are based on the principle that the correct weights may not be constant over the pose space and the way to get good results is to fix up and store numerous artist generated (or captured) examples at different poses and blend between them.

Le, Binh Huy, and Zhigang Deng. "Robust and accurate skeletal rigging from mesh sequences." ACM Transactions on Graphics (TOG) 33, no. 4 (2014): 1-10.
http://graphics.cs.uh.edu/ble/papers/2014s-ske/

Loper, Matthew, Naureen Mahmood, Javier Romero, Gerard Pons-Moll, and Michael J. Black. "SMPL: A skinned multi-person linear model." ACM transactions on graphics (TOG) 34, no. 6 (2015): 1-16. https://smpl.is.tue.mpg.de/

Finally, I mentioned that we must consider whether it is important to model the underlying anatomy to obtain good skinning results. This paper shows an example of the idea:

Ali-Hamadi, Dicko, Tiantian Liu, Benjamin Gilles, Ladislav Kavan, François Faure, Olivier Palombi, and Marie-Paule Cani. "Anatomy transfer." ACM Transactions on Graphics (TOG) 32, no. 6 (2013): 1-8.
https://dl.acm.org/doi/abs/10.1145/2508363.2508415