15-464 / 15-664 Reference List for Feb 17, 2021

We started with a brief review on the board of Jacobian based approaches to inverse kinematics taken from this paper, noting that these approaches have some limitations due to their iterative nature, slow speed, lack of repeatability, difficulty of selecting good parameters, and tendency to become "tangled up" for lengthy chains.   However, they are widely used and considered "go-to" techniques for character IK:

Buss, Samuel R. "Introduction to inverse kinematics with jacobian transpose, pseudoinverse and damped least squares methods." *IEEE Journal of Robotics and Automation* 17 (2004): 1-19. http://web.cse.ohio-state.edu/~parent/classes/694A/Lectures/Material/IKsurvey.pdf

My go-to reference for explaining these techniques and how to put them together into a character animation system is the following paper.   This paper uses the Jacobian damped pseudoinverse with nullspace projection to do character posing with a two-level priority system.   The point which the user clicks and drags is given top priority as the IK target, and secondary constraints include satisfying constraint points, moving the character towards a reference pose, and resolving joint limits.   These secondary constraints are satisfied as well as possible with secondary priority by cleverly making use of the opportunity to project desired goals into the nullspace associated with the top priority motion.

Yamane, Katsu, and Yoshihiko Nakamura. "Natural motion animation through constraining and deconstraining at will." *Visualization and Computer Graphics, IEEE Transactions on* 9, no. 3 (2003): 352-360. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1207443

The classic Jacobian based approach to IK has been parallelized to work quickly for many degree of freedom characters on a modern GPU.   We took a brief look at this paper, which is also worth reading for one more description of the classic Jacobian based approach to inverse kinematics.

Harish P, Mahmudi M, Callennec BL, Boulic R. Parallel inverse kinematics for multithreaded architectures. ACM Transactions on Graphics (TOG). 2016 May 25;35(2):19. http://dl.acm.org/citation.cfm?id=2887740

However, in some applications, even faster results may be desired.   For fast IK, CCD is the standby approach, as we saw last week.   However, CCD can create artifacts such as the end effector curling in on itself.   The following approach is also very fast and in the same style, but seems to create more visually pleasing and consistent results under some circumstances.

Aristidou, Andreas, and Joan Lasenby. "FABRIK: a fast, iterative solver for the inverse kinematics problem." *Graphical Models* 73, no. 5 (2011): 243-260. http://www.andreasaristidou.com/FABRIK.html https://www.youtube.com/watch?v=tN6RQ4yrNPU

You can see from the other papers listed on the same webpage that the authors have made this model work for humanoid characters, using heuristics to reconstruct full body character poses from a few markers or end effector trajectories.
https://www.youtube.com/watch?v=wjn19jBzJCE

The following classic IK paper points out that using iterative approaches does not really make sense if we only want the final pose.   Why not pose the problem as a more general optimization problem and let one of the vast library of solvers out there do the work of finding an answer?   I think this is an important idea that we should consider any time we are about to choose or implement an IK algorithm.

Zhao, Jianmin, and Norman I. Badler. "Inverse kinematics positioning using nonlinear programming for highly articulated figures." *ACM Transactions on Graphics (TOG)* 13, no. 4 (1994): 313-336.
http://ai.stanford.edu/~latombe/cs99k/2000/badler.pdf

Inverse kinematics is possible even when you have only a mesh and no skeleton at all.   We took a look at the following paper, which is the classic paper on this topic.   The second offers suggestions for improvements.

Sumner, Robert W., Matthias Zwicker, Craig Gotsman, and Jovan Popović. "Mesh-based inverse kinematics." In *ACM Transactions on Graphics (TOG)*, vol. 24, no. 3, pp. 488-495. ACM, 2005.
http://people.csail.mit.edu/sumner/research/meshik/

Wampler K. Fast and reliable example-based mesh IK for stylized deformations. ACM Transactions on Graphics (TOG). 2016 Nov 11;35(6):235.
http://dl.acm.org/citation.cfm?id=2982433

We went on to have a look at some more recent papers that all take somewhat different looks at the inverse kinematics problem.   The following paper covers posing using lines of action and has been used as a final project topic in this class.

Guay, Martin, Marie-Paule Cani, and Rémi Ronfard. "The line of action: an intuitive interface for expressive character posing." *ACM Transactions on Graphics (TOG)* 32, no. 6 (2013): 205.
https://team.inria.fr/imagine/the-line-of-action-an-intuitive-interface-for-expressive-character-posing/

This paper creates poses from silhouette drawings.   You may check whether their software is available online to try out.

Bessmeltsev M, Vining N, Sheffer A. Gesture3D: posing 3D characters via gesture drawings. ACM Transactions on Graphics (TOG). 2016 Nov 11;35(6):165.
http://dl.acm.org/citation.cfm?id=2980240
https://www.youtube.com/watch?v=8C3uZOXLBIA

This paper uses machine learning techniques to model human motion with the goal of constructing very realistic looking motions from a few "handles" or "pins."

Huang, Jing, Qi Wang, Marco Fratarcangeli, Ke Yan, and Catherine Pelachaud. "Multi-Variate Gaussian-Based Inverse Kinematics." In *Computer Graphics Forum*, vol. 36, no. 8, pp. 418-428. 2017. http://www.cse.chalmers.se/~marcof/publication/cgf2017/

This paper facilitates creation of animated versions of motion captured on video.

Willett, Nora S., Hijung Valentina Shin, Zeyu Jin, Wilmot Li, and Adam Finkelstein. "Pose2Pose: pose selection and transfer for 2D character animation." In *Proceedings of the 25th International Conference on Intelligent User Interfaces*, pp. 88-99. 2020. http://norawillett.com/pose2pose/index.html

And this paper brings many ideas together into a sketch based system for character creation and animation.

Dvorožňák, Marek, Daniel Sýkora, Cassidy Curtis, Brian Curless, Olga Sorkine-Hornung, and David Salesin. "Monster mash: a single-view approach to casual 3D modeling and animation." *ACM Transactions on Graphics (TOG)* 39, no. 6 (2020): 1-12. https://dcgi.fel.cvut.cz/home/sykorad/monster_mash

You may also be interested in this paper, which allows puppeteering non-humanlike characters using your entire body.   This one has been the topic of a final project for this class.   The students brought in a Kinect and let us try it out.

Seol Y, O'Sullivan C, Lee J. Creature features: online motion puppetry for non-human characters. InProceedings of the 12th ACM SIGGRAPH/Eurographics Symposium on Computer Animation 2013 Jul 19 (pp. 213-221). ACM. http://mrl.snu.ac.kr/publications/creatureFeatures/creatureFeatures.htm