Reference List for 15-464 / 15-664 March 4, 2020

We talked about how to set up a trajectory optimization by specifying a set of parameters, an objective function, and a collection of constraints. The paper used to focus the discussion was this one:

Pan, Zherong, Bo Ren, and Dinesh Manocha. "GPU-based contact-aware trajectory optimization using a smooth force model." In Proceedings of the 18th annual ACM SIGGRAPH/Eurographics Symposium on Computer Animation, pp. 1-12. 2019. http://gamma.cs.unc.edu/PBTO/

The trajectory optimization strategy we discussed in more detail came from this paper, which was one of the first to make it possible to optimize trajectories having contacts that were allowed to change dramatically throughout the optimization. This is made possible by having objective function terms that penalize (1) deviations from physical correctness, (2) bodies applying force while not in contact, (3) deviations from task goals, and (4) forces used to move the bodies around (e.g., muscle forces). The new feature of this paper was penalty term (2).

Mordatch, Igor, Emanuel Todorov, and Zoran Popović. "Discovery of complex behaviors through contact-invariant optimization." ACM Transactions on Graphics (TOG) 31, no. 4 (2012): 1-8. https://dl.acm.org/doi/10.1145/2185520.2185539
https://www.youtube.com/watch?v=mhr_jtQrhVA

I hope you all were able to see how any basic gradient based optimizer might be able to make progress towards objectives such as these, even when given very little information (e.g., just move the body from here to there).

I showed one example of my own trajectory optimization work with Anthony Fang, who had a beautiful idea about how to create smooth optimization spaces even for moderately complex characters (remember the green ellipsoid character?)

Fang, Anthony C., and Nancy S. Pollard. "Efficient synthesis of physically valid human motion." ACM Transactions on Graphics (TOG) 22, no. 3 (2003): 417-426.
http://graphics.cs.cmu.edu/nsp/projects/spacetime/spacetime.html

We then talked about an alternative to trajectory optimization that involves modeling muscle behavior and reflexes. We looked first at the research of Hartmut Geyer with his students, for example this paper:

Song, Seungmoon, and Hartmut Geyer. "A neural circuitry that emphasizes spinal feedback generates diverse behaviours of human locomotion." The Journal of physiology 593, no. 16 (2015): 3493-3511. https://www.cs.cmu.edu/~hgeyer/Research_MotorControl.html

This paper follows the same idea with the goal of making it work for various body shapes, including non-humanlike bodies.

Geijtenbeek, Thomas, Michiel Van De Panne, and A. Frank Van Der Stappen. "Flexible muscle-based locomotion for bipedal creatures." ACM Transactions on Graphics (TOG) 32, no. 6 (2013): 1-11. https://dl.acm.org/doi/10.1145/2508363.2508399
https://www.youtube.com/watch?v=pgaEE27nsQw

Finally we looked at the research of Karl Sims

Sims, Karl. "Evolving virtual creatures." In Proceedings of the 21st annual conference on Computer graphics and interactive techniques, pp. 15-22. 1994.
https://www.karlsims.com/evolved-virtual-creatures.html