High Performance Animation in Gears of War 4

Supplemental Material

David Bollo
Microsoft
dbollo@microsoft.com

ACM Reference format:
David Bollo. 2017. High Performance Animation in Gears of War 4. In *Proceedings of SIGGRAPH '17 Talks, Los Angeles, CA, USA, July 30 - August 03, 2017,* 1 pages.
https://doi.org/10.1145/3084363.3085069

A MOTION TRANSITION CURVES

Our Gears of War 4[1] motion transition method constructs a quintic polynomial interpolating curve that matches the pose difference and velocity at the beginning of the transition and converges to zero by the end of the transition.

At a given time t relative to the start of the current transition, we evaluate our quintic curve independently for each scalar degree of freedom in the pose. Let x_0 be the difference between the source and target poses at the start of the transition (i.e.: at $t = 0$):

$$x_0 = x_{source} - x_{target} \tag{1}$$

Similarly, let v_0 be the velocity of the source pose at the start of the transition. Note that we use the source's absolute velocity, rather than its velocity relative to the target. This is so that we do not need to evaluate a velocity term on the target pose. This approximation works well in practice and saves us from having to evaluate two frames of the target animation on the first frame of the transition (to derive its velocity term).

Let t_1 be the duration of our transition. Obviously, if $t \leq 0$, we are evaluating the curve before the beginning of the transition, so we use the source pose as is. Similarly, if $t \geq t_1$, we are evaluating the curve beyond the end of the transition, so we use the target pose as is.

To simplify our calculations, we assume that x_0 is positive. If it is negative, we simply negate x_0 and v_0 and continue with the calculations as before, making sure to also negate the resulting x from equation 7.

At this point, if v_0 is greater than zero, then the curve is initially moving away from the target pose. As we wish to guard against overshoot (effectively bracketing our result to be between the source and target poses), we clamp v_0 to be zero in this case.

We next limit t_1 such that the curve does not overshoot below zero. We observe that if the curve does overshoot below zero, it must have an inflection point between 0 and t_1 (since we know that both x_0 and x_1 are both non-negative). Therefore, we can prevent overshoot by adjusting t_1 such that any inflection point is at $t \geq t_1$. We limit t_1 to be the lesser of itself or of t_1':

$$t_1' = -5\frac{x_0}{v_0} \tag{2}$$

As t_1 may have now been shifted earlier, we repeat our check to see if we are evaluating beyond the end of the transition window. If $t \geq t_1$, we simply use the target pose as is.

We choose to use a quintic polynomial both because it fits well with the experimentally observed motion of humans [Flash and Hogan 1985], but also because it gives us the ability to freely control the initial acceleration at the start of the transition. We choose an initial acceleration of zero except in situations with a large negative initial velocity, in which case we adjust the initial acceleration in order to ensure that the curve does not overshoot (i.e.: to ensure that $x \geq 0$ for all t between 0 and t_1).

To compute this initial acceleration a_0, we first compute the a_0 that gives us a zero third derivative (jerk) at t_1:

$$a_0 = \frac{-8t_1v_0 - 20x_0}{t_1^2} \tag{3}$$

If a_0 from equation 3 is positive (and therefore opposing the initial velocity), then we use that. Otherwise, we simply set $a_0 = 0$.

Finally, given this initial acceleration, we can compute the value x of the quintic curve at the requested time t:

$$A = \frac{a_0t_1^2 + 6t_1v_0 + 12x_0}{t_1^5} \tag{4}$$

$$B = \frac{3a_0t_1^2 + 16t_1v_0 + 30x_0}{t_1^4} \tag{5}$$

$$C = \frac{3a_0t_1^2 + 12t_1v_0 + 20x_0}{t_1^3} \tag{6}$$

$$x = \frac{-At^5 + Bt^4 - Ct^3 + a_0t^2}{2} + v_0t + x_0 \tag{7}$$

The resulting smoothed pose is then calculated by adding x to the current (at time t) value of the target pose.

REFERENCES

T. Flash and N. Hogan. 1985. The Coordination of Arm Movements: An Experimentally Confirmed Mathematical Model. *Journal of Neuroscience* 5, 7 (July 1985), 1688–1703.

SIGGRAPH '17 Talks, July 30 - August 03, 2017, Los Angeles, CA, USA

ACM ISBN 978-1-4503-5008-2/17/07.
https://doi.org/10.1145/3084363.3085069