Animation, Simulation, Color, and Imaging 11

CS184: Computer Graphics and Imaging

April 16, 2019

1 Animation and Physical Simulation

1. What are keyframes and what do we do with them?

   Solution: Keyframes, as their name suggests, are the important moments in some transition or motion, usually the starting and ending points. We usually interpolate between them (though not linearly, because usually too complex) in order to create the frames between the keyframes to form fluid video - the process of creating the intermediate frames is known as tweening.

2. What is the difference between forward and inverse kinematics? What are some problems associated with the latter?

   Solution: Forward - we provide angles (e.g. for joints), computer determines final position (e.g. of end of limbs).

   Inverse - we provide ending position, need to compute the joint angles to reach the position.

   Difficulties with inverse kinematics - sometimes has multiple possible solutions (sometimes connected to each other, sometimes separate), sometimes has no solutions, want to make sure solution found is realistic, etc.

3. Recall the forward, or explicit Euler method, which uses the following update rules:

$$\boldsymbol{x}^{t+\Delta t} = \boldsymbol{x}^t + \Delta t \dot{\boldsymbol{x}}^t$$
$$\dot{\boldsymbol{x}}^{t+\Delta t} = \dot{\boldsymbol{x}}^t + \Delta t \ddot{\boldsymbol{x}}^t$$

where $\boldsymbol{x}^t, \dot{\boldsymbol{x}}^t, \ddot{\boldsymbol{x}}^t$ respectively denote the position, velocity, and acceleration at time t.

(a) Give some pros and cons of using the explicit Euler method.

(b) Say we have a particle with mass 1 starting at position $\boldsymbol{x}^0 = (0, 1)$ with an initial velocity $\dot{\boldsymbol{x}}^0 = (-1, 0)$ and no initial acceleration. The particle is at one end of a spring, whose other end is the origin $(0, 0)$, and whose spring constant is $k = 1$ and rest length is 1. Calculate particle's position at $t = 3$ using the explicit Euler method with timestep $\Delta t = 1$.

Solution:

(a) Pros - simple and easy to compute, we don't always care about precision in graphics (i.e. close enough is good enough).

Cons - inaccurate and unstable, which frequently leads to divergent results, especially as time progresses and errors accumulate.

(b)

$$\boldsymbol{x}^0 = (0, 1) \qquad \dot{\boldsymbol{x}}^0 = (-1, 0) \qquad \ddot{\boldsymbol{x}} = (0, 0)$$

$$\boldsymbol{x}^1 = (-1, 1) \qquad \dot{\boldsymbol{x}}^1 = (-1, 0)$$

$$\ddot{\boldsymbol{x}}^1 = \frac{F_s}{m} * \frac{(0,0) - (-1,1)}{||(0,0) - (-1,1)||} = \frac{1 * (\sqrt{2} - 1)}{1} * (\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}) = (1 - \frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2} - 1)$$

$$\boldsymbol{x}^2 = (-2, 1) \qquad \dot{\boldsymbol{x}}^2 = (-\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2} - 1) \qquad \ddot{\boldsymbol{x}}^2 = \text{unneeded}$$

$$\boldsymbol{x}^3 = (-2 - \frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}) \qquad \dot{\boldsymbol{x}}^3 = \text{unneeded} \qquad \ddot{\boldsymbol{x}}^3 = \text{unneeded}$$

2 Sensors

1. What is ISO, or gain, and how is it related to exposure?

Solution: ISO (gain) can be thought of as a third variable related to exposure, along with irradiance and exposure time. It represents the sensitivity of the sensor to light. For analog cameras, physical film trades sensitivity for grain while digital cameras trade sensitivity for noise in the captured images.

ISO scales inversely with the amount of light required. A photo taken with a camera set at 200 ISO needs only half as much light as a photo taken with a camera set at 100 ISO.

2. What is signal-to-noise ratio (SNR), and how is it mathematically defined?

Solution: The signal-to-noise ratio (SNR) is the ratio between the average pixel value and the standard deviation of the pixel value. In short, it can be written as SNR = $\frac{\mu}{\sigma}$. It is also commonly talked about in a logarithmic scale using units of decibels: SNR (dB) = $20log_{10}(\frac{\mu}{\sigma})$.

3. If we assume that photons arrive on the image sensor according to a Poisson distribution, then SNR scales with the square root of the number of photons. This means that as I acquire more photons, the overall noise in my image will decrease (which should match our intuition). If I want increase my SNR by a factor of 2, how should I change the size of my aperture?

Solution: Given the Poisson distribution of photon arrival, we know that SNR = $\sqrt{\lambda}$, where λ is the number of photons. To double our SNR, we will require $2\sqrt{\lambda} = \sqrt{4\lambda} \rightarrow 4\lambda$ photons, which is 4 times as many photons as we had before.

We know that opening our aperture by 1 f-stop will double the number of photons, so to get 4 times as many photons, we will need to open our aperture by 2 f-stops. Recall that the squareroot of aperture size is proportional to the number of photons (e.g. increasing by 1 f-stop means double photons means $\sqrt{2}$ larger aperture size). Therefore, opening our aperture by 2 f-stops means doubling our aperture size.

3 Colors

1. What is a metamer? Why are metamers useful?

Solution: Metamers are two different spectra that integrate to the same visual (S, M, L) response. They are useful because we can reproduce real-world scenes with hard-to-recreate spectra on screens.

2. What are some common problems associated with defining a color space?

Solution: Device-dependent, limited gamut

3. What is the purpose of the CIE chromaticity diagram and how is it read? Why is black not on this diagram?

Solution: Pure (spectral) colors are at the edge of the plot and become more desaturated as you go towards the centroid of the plot. Black is not on this diagram because it is purely a chromaticity diagram - luminance values are dealt with separately.

4. What is the goal of the CIELAB color space?

Solution: Perceptual uniformity across colors. L* is lightness, a* is red-green, and b* is blue-yellow.