

Antler Sample Documentation

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Contents

Rotating Cube	5
GNU Free Documentation License	9
1. APPLICABILITY AND DEFINITIONS	9
2. VERBATIM COPYING	11
3. COPYING IN QUANTITY	12
4. MODIFICATIONS	12
5. COMBINING DOCUMENTS	14
6. COLLECTIONS OF DOCUMENTS	15
7. AGGREGATION WITH INDEPENDENT WORKS	15
8. TRANSLATION	16
9. TERMINATION	16
10. FUTURE REVISIONS OF THIS LICENSE	17
11. RELICENSING	17
ADDENDUM: How to use this License for your documents	18

Rotating Cube

This sample consists of a uniform density cube rotating about its center of mass. With fixed mass, the size of the cube oscillates, and the torque generated changes the cube's rotational velocity. Basic diffuse lighting gives the cube some extra dimensionality, with the static camera acting as a point source of light.

Let t represent simulation time. For unit mass m and side length $s(t)$, the rotational inertia tensor $I(t)$ is simply a scaling of the identity matrix.

$$I(t) = \frac{1}{6} * m * s(t)^2 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Let $\omega(t)$ represent the rotational velocity psuedovector. For fixed mass, conservation of rotational momentum demands

$$I(t)\omega(t) = I(0)\omega(0)$$

$$s(t)^2\omega(t) = s(0)^2\omega(0). \tag{1}$$

Now we need to integrate $\omega(t)$. To do this, first we must decide how the side-length of the cube will vary with time. Periodicity provides nice properties, and the side-length must be strictly greater than zero to avoid violating Eq.(1). To avoid numerical integration, we pick something nice and easy.

$$s(t) = \left[a + b * \sin\left(\frac{2\pi t}{T}\right) \right]^{-1/2}, a > b. \tag{2}$$

By Eq.(1) and Eq.(2),

$$\omega(t) = \left[1 + \frac{b}{a} * \sin\left(\frac{2\pi t}{T}\right) \right] * \omega(0). \tag{3}$$

When programming this, omega may be converted into an axis-angle representation. The axis is equal to the normalization of $\omega(t)$. Consequently this is equivalent to the normalization of $\omega(0)$, which is fixed over time. By Eq.(3), the angular speed is given by

$$\nu(t) = \left[1 + \frac{b}{a} * \sin\left(\frac{2\pi t}{T}\right) \right] * \nu(0), \quad (4)$$

where $\nu(0)$ is the norm of $\omega(0)$. Because $a > b$, the maximum value for ν can never quite reach $2\nu(0)$, and the minimum value ν is always positive, but never quite zero. Now we integrate $\nu(t)$ into a function called $\theta(t)$.

$$\theta(t) = \left[t + \frac{bT}{2a\pi} * \cos\left(\frac{2\pi t}{T}\right) \right] * \nu(0) + C.$$

By $\theta(0) = 0$, $C = bT\nu(0)/2a\pi$. Thus

$$\theta(t) = \left[t + \frac{bT}{2a\pi} * \left(1 - \cos\left(\frac{2\pi t}{T}\right) \right) \right] * \nu(0). \quad (5)$$

We have an analytic expression for θ , rather than using a time step and an integration technique. Consequently, naively plugging in an ever-increasing value for t will eventually cause large precision error. The simulation likely won't run so long, but I'll consider this an extra feature (this is where the periodicity of $s(t)$ comes in). Restrict t to the interval $[0, T)$; if $n \in \mathbb{N}$, then by Eq.(2) and Eq.(5),

$$s(t + nT) = \left[a + b * \sin\left(\frac{2\pi t}{T}\right) \right]^{-1/2}, \text{ and}$$

$$\theta(t + nT) - \theta(nT) = \left[t - \frac{bT}{2a\pi} * \cos\left(\frac{2\pi t}{T}\right) \right] * \nu(0).$$

Now let's discuss how this would look in code. The application loop consists of an inner update loop which operates at a fixed time step, an interpolation step, and a render step. Initialize the variables α , s , and θ to zero. The update procedure is as follows:

1. Update simulation time t . If t leaves the interval $[0, T)$, shift it by subtracting T , and count the number of shifts as n . For nonzero n , update α by adding $nT\nu(0)$. If α is not in the interval $[0, 2\pi)$, shift it in steps of 2π until it is.

2. Store s from the previous update frame. Set

$$s = \left[a + b * \sin \left(\frac{2\pi t}{T} \right) \right]^{-1/2}.$$

3. Store θ from the previous update frame. Set

$$\theta = \alpha + \left[t - \frac{bT}{2a\pi} * \cos \left(\frac{2\pi t}{T} \right) \right] * \nu(0).$$

Naive individual shifts or clamps will cause problems when interpolating between update frames. Determine the shift that brings θ of the current frame into the interval $[0, 2\pi)$. Then shift θ of the previous frame by the exact same amount.

During the interpolation step, s and θ are interpolated between update frames. s is linearly interpolated and θ is interpolated with slerp.

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