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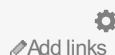
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Cone tracing

From Wikipedia, the free encyclopedia

Cone tracing^[1] and **beam tracing** are a derivative of the **ray tracing algorithm** that replaces rays, which have no thickness, with thick rays.

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Principles

This is done for two reasons:

From a physics of light transport point of view

The energy reaching the pixel comes from the whole **solid angle** by which the eyes see the pixel in the scene, not from its central sample. This yields the key notion of **pixel footprint** on surfaces or in the texture space, which is the back projection of the pixel on the scene.

The description above corresponds to the **pinhole camera** simplified optics classically used in **computer graphics**. Note that this approach can also represent a lens-based camera and thus **depth of field** effects, using a cone whose cross-section decreases from the lens size to zero at the **focal plane**, and then increases.

Moreover, a real optical system does not focus on exact points because of **diffraction** and imperfections. This can be modeled as a **point spread function** (PSF) weighted within a solid angle larger than the pixel.

From a signal processing point of view

Ray-tracing images suffer strong **aliasing** because the "projected geometric signal" has very high frequencies exceeding the **Nyquist-Shannon maximal frequency** that can be represented using the pixel sampling rate, so that the input signal has to be low-pass filtered - i.e., integrated over a solid angle around the pixel center.

Note that contrary to intuition, the filter should not be the pixel footprint since a **box filter** has poor spectral properties. Conversely, the ideal **sinc function** is not practical, having infinite support and possibly negative values. A **Gaussian** or a **Lanczos** filter are considered good compromises.

Computer graphics models

Cone and Beam early papers rely on different simplifications: the first considers a circular section and treats the intersection with various possible shapes. The second treats an accurate pyramidal beam through the pixel and along a complex path, but it only works for polyedrical shapes.

Cone tracing solves certain problems related to **sampling** and **aliasing**, which can plague conventional ray tracing. However, cone tracing creates a host of problems of its own. For example, just intersecting a cone with scene geometry leads to an enormous variety of possible results. For this reason, cone tracing has remained mostly unpopular. In recent years, increases in computer speed have made **Monte Carlo** algorithms like **distributed ray tracing** - i.e. stochastic explicit integration of the pixel - much more used than cone tracing because the results are exact provided enough samples are used. But the convergence is so slow that even in the context of off-line rendering a huge amount of time is required to avoid **noise**.

Differential cone-tracing, considering a differential angular neighborhood around a ray, avoids the complexity of exact geometry intersection but requires a LOD representation of the geometry and appearance of the objects. **MIPmapping** is an approximation of it limited to the integration of the surface texture within a cone footprint. Differential ray-tracing ^[2] extends it to textured surfaces viewed through complex paths of cones reflected or refracted by curved surfaces. The full differential cone-tracing - including geometry and appearance filtering - is mostly applicable as volumetric cone-tracing,^[3] relying on 3D **MIPmapping**.

A recent [SVO](#) implementation by Crassin *et al.*^[4] has generalized this approach to [global illumination](#) and adapted it to GPU, showing remarkable quality images at 25–70 frames per second.^[5]

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