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Efficient and Robust Ray Intersection

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I. Ray Intersection is Important for Computer Graphics

The generation of ray traced images of a variety of surfaces play a central role in computer graphics.

One of the central operations in ray tracing is the calculation of *intersections* between rays and surfaces.

II. Ray Intersection as a Mathematical Problem

In the case of implicitly given surfaces, the intersection problem can be formulated as that of finding the first non-negative root of a single equation in one variable (i.e. a non-negative root closest to zero).

III. Traditional Numerical Methods Can Lead to a Wrong Image

If traditional numerical methods are used for the root finding, the resulting image may be very wrong: e.g., when the surface is thin, the ray may "miss" the surface, and a possible result is an image with background colour spots in the image of the surface.

IV. Interval Methods Lead to a Robust (Guaranteed) Intersection Detection

To obtain a safe (robust) intersection detection, an interval based bisection method combined with a safe interval test for uniqueness ($F'(X)$ does not contain zero) has been used to isolate the first root, and a traditional method such as Newton's method has been used to refine the isolated root [1].

V. The New Method of Robust Ray Intersection

In this paper, we apply a variant of Hansen's globally convergent method for computing and bounding all the roots of a single equation [2]. Hansen's method has been modified as follows: instead of searching for all roots, a recursive depth-first search is carried out to obtain the first non-negative root.

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VI. The New Method Is More Efficient

It is found that this variant of Hansen's method is a more efficient method for isolation of the first root when compared to simple interval based bisection.

Furthermore, even if the first root is safely isolated, the traditional Newton method may diverge or fail to converge to the first root. This problem is avoided in the described variant of Hansen's method.

References

[1] Don P. Mitchell, "Robust Ray Intersection with Interval Arithmetic", *Proceedings of Graphics Interface '90*, May 1990, pp. 68–74.

[2] E. Hansen, "Globally Convergent Interval Method for Computing and Bounding Real Roots", *BIT*, 1978, Vol. 18, pp. 415–424.