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Ray-triangular Bézier patch intersection using hybrid clipping algorithm

Key words: Ray tracing, Triangular Bézier surface, Ray-patch intersection, Root-finding, Hybrid clipping

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Motivation

- Ray tracing is a valuable tool for rendering scenes with amazing realistic light effects in computer graphics, and its efficiency relies heavily on the computation of the ray and object intersection test.
- Objects in the scene vary from simple triangles to complex surfaces, such as parametric splines and implicit surfaces. Among them, triangular Bézier patches have been accepted as a primitive choice by the modeling community because of their flexibility in modeling objects with complicated topology.
- However, the intersection test for a ray with objects is a nontrivial technique even for the simplest case.

Main idea

- Our method combines convex hulls and low-degree approximations of triangular Bézier surfaces, which gradually cuts out the parametric region without intersections until a pre-specified accuracy threshold is reached.
- The proposed method is numerically more stable and require less memory than the space partition method and Newton's method. Theoretical analysis shows that our algorithm has a cubic convergence rate for a single root.

Method

1. We reduce the ray-patch intersection problem to an equivalent problem of solving a system of two bivariate equations.
2. The roots of system are precisely the intersections of the two curves defined by equations of the system within a tri-box. Then both the curves are individually bounded in a strip (called as a fat curve) formed by a pair of curves obtained by a degree reduction method.

Method

3. By calculating the intersections between fat curves and using the subdivision method, we obtain sub-tri-boxes with the intersections of the original curves within them.
4. The aforementioned procedure is repeatedly applied until the diameter of the sub-tri-box becomes smaller than a pre-specified threshold.

Major results

- We theoretically prove and experimentally verify that our algorithm (hybrid clipping (HC) method) provides cubic convergence for a single root.
- Numerical experiments showed that for systems with a double root or with two different roots that are close to each other, the HC method is more efficient than other compared methods, owing to the preprocessing step.

Conclusions

- We proposed a new technique called hybrid clipping (HC) method to solve the ray patch intersection problem, which is cubic convergence rate for a single root.
- A preprocessing step is suggested in the HC method for systems with a double root. However, we currently have no advanced idea on the number and multiplicity of the roots of systems. One of our future works is to provide an appropriate indicator to turn on/off the preprocessing step and produce the best trade-off between preprocessing time and total computation time.