SWIFT: General Polyhedral Proximity Query

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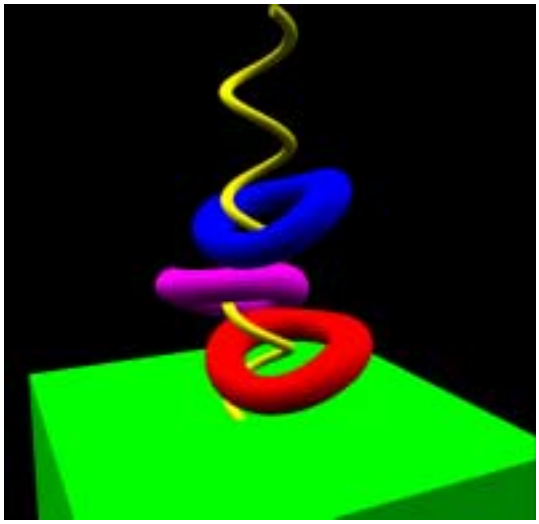
The Challenge

Determining information about the relative positions of two virtual objects is a fundamental problem in computer animation, computer graphics, physically based modeling, and robotics. Algorithms have been proposed to solve certain aspects of the problem, such as intersection detection and distance computation. Existing algorithms are also sometimes restricted to certain classes of models, such as convex polyhedra. It is desirable to have a framework that allows any sequence of proximity queries to be performed efficiently for a useful class of models.



A frame from a dynamic simulation of three tori falling down a spiral.

The Approach

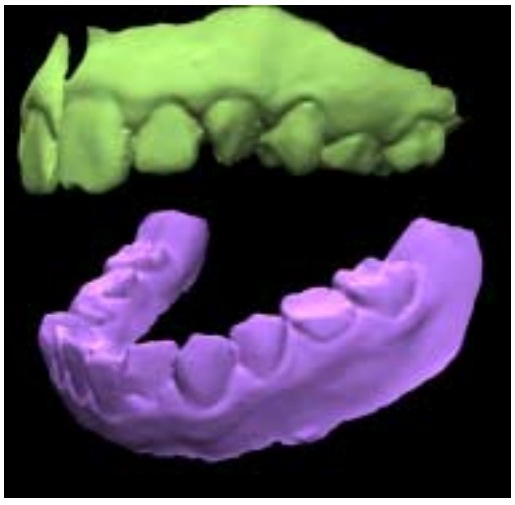
SWIFT is an exact collision-detection library for environments composed of general polyhedral solids undergoing rigid motion. It handles multiple types of queries such as intersection detection, distance computation, and contact determination, in a unified framework. The algorithm proceeds in three stages. The first two involve pre-computation.

First, an input polyhedron is decomposed into convex surface patches. This is done by using a breadth-first search on the dual graph of the polyhedra while maintaining a convex hull using the insertion hull algorithm. The convex hull of the convex surface elements is then taken to construct convex pieces. The second stage groups these pieces hierarchically using convex hull bounding volumes. The primitives, as well as the bounding volumes, are convex polyhedra.

Highlights

- **Use of convexity and hierarchical refinement to accelerate proximity queries between two general polyhedral models.**
- **A unified framework for proximity queries including intersection detection, tolerance verification, approximate and exact minimum distance computation, and contact determination.**
- **A suite of query acceleration techniques that exploit temporal and spatial coherence: piece caching, priority directed search, and generalized front tracking.**

Any two bounding volumes, a bounding volume and a primitive, or two primitives may be tested using a subroutine for testing a pair of convex polyhedra. This subroutine is based on the Lin and Canny closest features algorithm. The third stage (query) occurs at runtime. The answer to many proximity queries can be computed by an appropriate traversal of a pair of bounding volume hierarchies. Because of the convex hull bounding volume property, entire sub-trees can potentially be culled after testing their root nodes. We have generalized and implemented three optimizations that exploit coherence. They are piece caching, priority directed searching, and generalized front-tracking.



A frame from a tolerance verification run on a scanned model of some teeth.

Combining all these ideas into a single framework yields a powerful proximity system.

The source code that is available for SWIFT can handle compositions of convex polyhedra. It includes an implementation of sweep-and-prune to quickly find the pairs that need further testing.

Project Leaders

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Graduate Research Assistants

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Research Sponsors

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Selected Publications

Ehmann, S. A., and M. C. Lin. "Accelerated Proximity Queries Between Convex Polyhedra By Multi-Level Voronoi Marching," *Proc. International Conference on Intelligent Robots and Systems*, 2000.

Ehmann, S. A., and M. C. Lin. "Accurate and Fast Proximity Queries Between Polyhedra Using Convex Surface Decomposition," *Department of Computer Science Technical Report, University of North Carolina*, 2001.

Key Words

Collision detection; tolerance verification; distance computation; contact determination; dynamic simulation; hierarchical data structures.

For More Information

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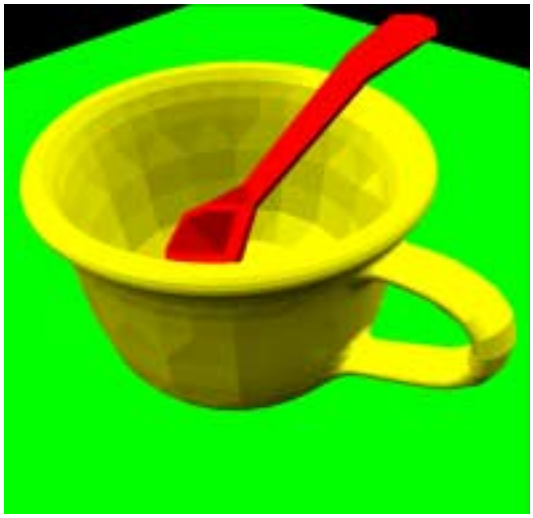

A frame from a dynamic simulation of a spoon falling into a cup.

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