A Benchmarking Suite for Static Collision Detection Algorithms

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Motivation

- Fast algorithms for collision detection between polygonal objects play an important role in many applications
  - Physically based simulations
  - Entertainment
  - Robotics

- Collision Detection is computational bottleneck
  → Essential to select fastest algorithm
Requirements

- Collision detection algorithms are sensitive to specific scenarios
  - Difficult to evaluate and compare

- Standardized benchmarking suite for collision detection should make fair comparisons between algorithms much easier
  - Broad spectrum of interesting contact scenarios
  - Easy to use
  - Flexible and robust
Related Work

- One object rotates in several fixed distances to another object [Zachmann, 98]
  - objects penetrate heavily
- Benchmark with special focus on motion planning [Caselli et al., 02]
- Physically based simulation
  [Otaduy & Lin, 03]
Our Approach

- Running time depends mainly on
  - object shapes
  - objects complexity
  - orientation
  - distance between the objects
- Test as many configurations for a given distance as possible
  - Use a set of different objects in several resolutions
  - Compute user specified number of configurations for a given distance
Distance Computing: Offset Surface
Distance Computing: PQP

Motivation

Benchmarking Algorithms

Results

Conclusions
Sampling the Search Space

- 6D continuous search space is too big to be tested
  → Sampling

- Two Methods:
  - Grid Method
    - More Accurate
  - Sphere Method
    - Faster

- Main Loop:

```python
while #Rotations < Required #Rotations
    Do method specific translations
    Rotate moving object
```
Sphere Method
Problems of the Sphere Method
Grid Method
Implementation

- OpenSG for object management
- Wrapper for several free available CD-libraries
- For configuration space exploration user has to specify:
  - Objects
  - Preferred Method
  - Grid size/ step size for spherical coordinate
  - Step size for rotation of the moving object
  - Set of distances
- Automatical generation of sample points and benchmark of all available algorithms with accuracy of 1 msec
Libraries for Collision Detection

- **VCollide**
  - Interface for I-Collide and RAPID
  - Sweep-and-Prune (disabled)
  - OBBs

- **PQP**
  - Bases on RAPID (OBBs)
  - Supports Distance Computing
    - Swept spheres
Libraries for Collision Detection

- FreeSolid
  - AABBs
  - Could handle deformations

- Opcode
  - Memory optimized AABBs (no-leaf-trees)
  - Uses primitive-BV-tests

- BoxTree
  - Memory optimized AABBs
  - 2 splitting planes instead of 6 extends
  - Supports grid and convex hull pre-tests for n-body simulations (disabled)
Libraries for Collision Detection

- Dop-Tree
  - Discretely oriented polytopes (k-Dops)
  - $k = 24$ for highest performance in most cases
  - Supports convex-hull pre-checks and grid for n-body simulation (disabled)
Test Cases

- 20 different kinds of objects in different resolutions
  - Helicopter, lustre, chair, castle, car models, space vehicles, different synthetic objects

- Sphere method with PQP
  - 15° steps for spherical coordinates
  - 60° steps for rotations
  - P4 3.0 Ghz, 1GB, gcc 4.0.2 on Linux
Results
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Conclusions and Future Work

- Easy to use benchmarking suite and a set of representative objects for benchmarking CD algorithms for rigid objects
- Robust, fast, flexible and it is easy to integrate other libraries
- In the Future
  - Extend it for penetrating objects
  - Continuous collision detection
  - Deformable objects
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