A Benchmark for Distance Measurements

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The Distance Problem

Many problems in computer graphics (collision detection, boolean intersection, etc.) can be reduced to distance measurements:

- Two triangle meshes $T^1 = \{t^1_1, \ldots, t^1_m\}$ and $T^2 = \{t^2_1, \ldots, t^2_n\}$
- and the Euclidean distance function d_{ij} between the triangles t^1_i and t^2_j are given.
- Determine the minimum of all distances

$$\{d_{11}, \ldots, d_{1n},\ \ d_{21}, \ldots, d_{2n},\ \ d_{m1}, \ldots, d_{mn}\}$$

and list all pairs (i, j) which take the minimum value.

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- and the Euclidean distance function d_{ij} between the triangles t_i^1 and t_j^2 are given.
- Determine the minimum of all distances

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In theory, the distance problem has quadratic complexity
(in the worst case, all pairs $(1, 1), \ldots, (n, m)$ have to be reported).

**In theory there is no difference
between theory and practice.
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A Benchmark for Distance Measurements

The benchmark consists of:

- five test scenarios
  1. Tools Test
     "average" case
  2. Rosetta Test
     different scales
  3. Spirit Test
     heterogeneous tessellation
  4. Sphere Test
     linear complexity
  5. Intersection Test
     quadratic complexity

- in 13 different sizes
  1. 100 elements
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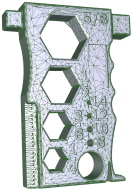
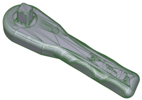
Benchmark for Distance Measurements: Tools Test

The first test scenario represents an “average” case without any special triangle configurations.

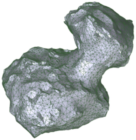




A good-case-scenario: both models have a similar complexity (number of triangles), a similar size (AABB volume) and the distance to each other is in the same order of magnitude.

Benchmark for Distance Measurements: Rosetta Test

The second test scenario is designed to represent a CAD-application test of extremely different sizes.



Besides the model size with respect to the number of vertices and faces, the problem is the different scale of the objects (km vs. m) and the unbalanced distribution of geometric elements in space with a triangle cluster at the space probe; i.e. any spatial data structure has to cope with element clusters.

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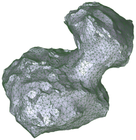

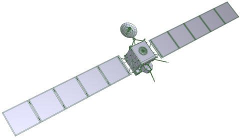

enlarged for a better view

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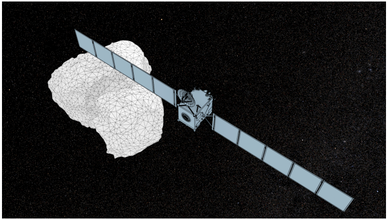

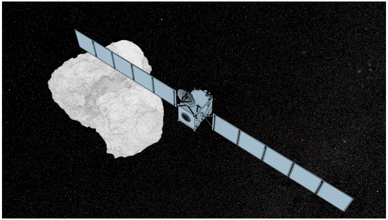

The Rosetta Test configuration with the a resolution model (left) and a high resolution model (right): 67P/Churyumov-Gerasimenko is $\approx$5km in diameter, the space probe is $\approx$32m $=$ 0.032km in diameter, their distance to each other is $\approx$15km.

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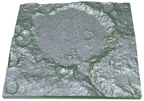
Benchmark for Distance Measurements: Spirit Test

The second test scenario consists of two heterogeneously tessellated models in a configuration with elements in very different scales.



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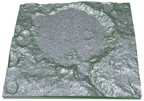

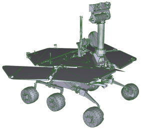

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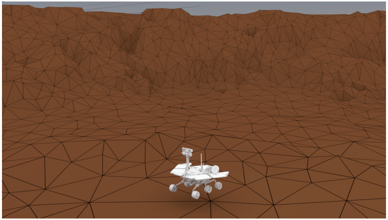
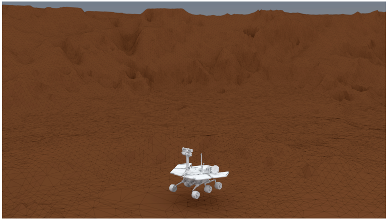
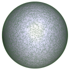




The Spirit Test configuration with the a resolution model (left) and a high resolution model (right): the landing site has a very heterogeneous tessellation.

Benchmark for Distance Measurements: Sphere Test

The fourth test scenario comprehends an artificial and challenging configuration. Each test consists of one triangulation of random points uniformly distributed on a sphere scaled by two different factors (radius $r_1 = 1$ and $r_2 = 2$).



Consequently, a test configuration with n elements in each data set should report $O(n)$ pairs with a distance ≈ 1.

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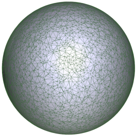

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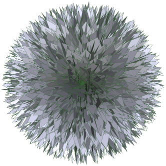
Benchmark for Distance Measurements: Intersection Test

The fifth test scenario implements the algorithmic worst case; all triangles pass through **one point**.



This pathological case requires a minimum runtime of $O(n^2)$ for any spatial acceleration structure. Although this test may have reduced practical relevance, it often points out weaknesses in implementations.

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Publicly available at **https://github.com/FhA-VC**

All data sets may be used for non-commercial purposes.