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Bowyer–Watson algorithm

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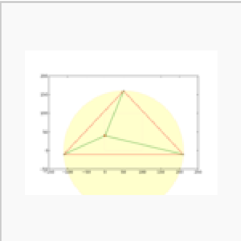
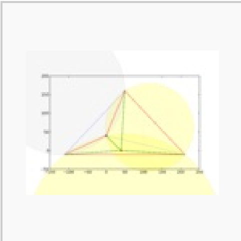
In computational geometry, the **Bowyer–Watson algorithm** is a method for computing the Delaunay triangulation of a finite set of points in any number of dimensions. The algorithm can be used to obtain a Voronoi diagram of the points, which is the dual graph of the Delaunay triangulation.

The Bowyer–Watson algorithm is an incremental algorithm. It works by adding points, one at a time, to a valid Delaunay triangulation of a subset of the desired points. After every insertion, any triangles whose circumcircles contain the new point are deleted, leaving a star-shaped polygonal hole which is then re-triangulated using the new point. By using the connectivity of the triangulation to efficiently locate triangles to remove, the algorithm can take *O(N log N)* operations to triangulate N points, although special degenerate cases exist where this goes up to $O(N^2)$.[1]

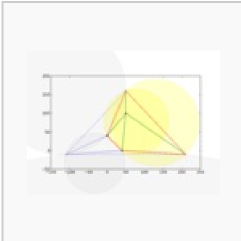
The algorithm is sometimes known just as the **Bowyer Algorithm** or the **Watson Algorithm**. Adrian Bowyer and David Watson devised it independently of each other at the same time, and each published a paper on it in the same issue of *The Computer Journal* (see below).



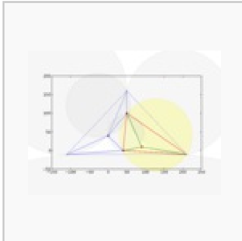
First step: insert a node in an enclosing "super"-triangle



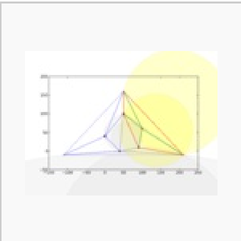
Insert second node



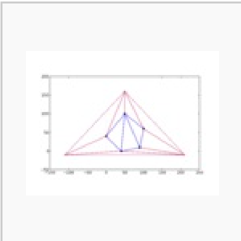
Insert third node



Insert fourth node



Insert fifth (and last) node



Remove super-triangle edges

Pseudocode [edit]

The following pseudocode describes a basic implementation of the Bowyer-Watson algorithm. Efficiency can be improved in a number of ways. For example, the triangle connectivity can be used to locate the triangles which contain the new point in their circumcircle, without having to check all of the triangles. Pre-computing the circumcircles can save time at the expense of additional memory usage. And if the points are uniformly distributed, sorting them along a space filling Hilbert curve prior to insertion can also speed point location.[2]

```
function BowyerWatson (pointList)
   // pointList is a set of coordinates defining the points to be triangulated
   triangulation := empty triangle mesh data structure
   add super-triangle to triangulation // must be large enough to completely contain all the points in pointList
   for each point in pointList do // add all the points one at a time to the triangulation
      badTriangles := empty set
      for each triangle in triangulation do // first find all the triangles that are no longer valid due to the insertion
         if point is inside circumcircle of triangle
```

```
            add triangle to badTriangles
         polygon := empty set
         for each triangle in badTriangles do // find the boundary of the polygonal hole
            for each edge in triangle do
               if edge is not shared by any other triangles in badTriangles
                  add edge to polygon
         for each triangle in badTriangles do // remove them from the data structure
            remove triangle from triangulation
         for each edge in polygon do // re-triangulate the polygonal hole
            newTri := form a triangle from edge to point
            add newTri to triangulation
      for each triangle in triangulation // done inserting points, now clean up
         if triangle contains a vertex from original super-triangle
            remove triangle from triangulation
      return triangulation
```

See also [edit]

- Fortune's algorithm
- Delaunay triangulation
- Computational geometry

References [edit]

1. ^ Rebay, S. *Efficient Unstructured Mesh Generation by Means of Delaunay Triangulation and Bowyer-Watson Algorithm*. Journal of Computational Physics Volume 106 Issue 1, May 1993, p. 127.
2. ^ Liu, Yuanxin, and Jack Snoeyink. "A comparison of five implementations of 3D Delaunay tessellation." Combinatorial and Computational Geometry 52 (2005): 439-458.

- Bowyer, Adrian (1981). "Computing Dirichlet tessellations". *Comput. J.* **24** (2): 162–166. doi:10.1093/comjnl/24.2.162.
- Watson, David F. (1981). "Computing the *n*-dimensional Delaunay tessellation with application to Voronoi polytopes". *Comput. J.* **24** (2): 167–172. doi:10.1093/comjnl/24.2.167.
- Efficient Triangulation Algorithm Suitable for Terrain Modelling generic explanations with source code examples in several languages.

Categories: Geometric algorithms

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