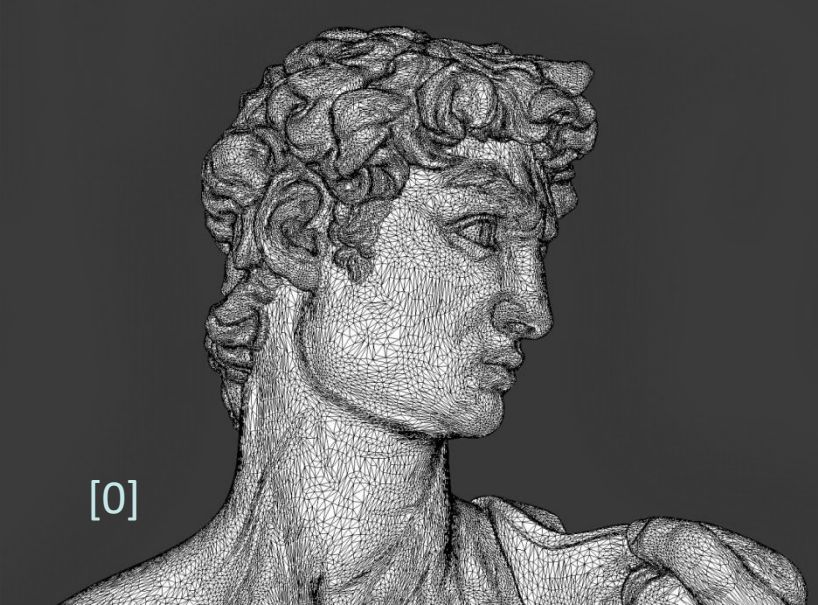
Fast surface reconstruction methods with Delaunay triangulation

Miguel Pedregosa Pérez



[0]

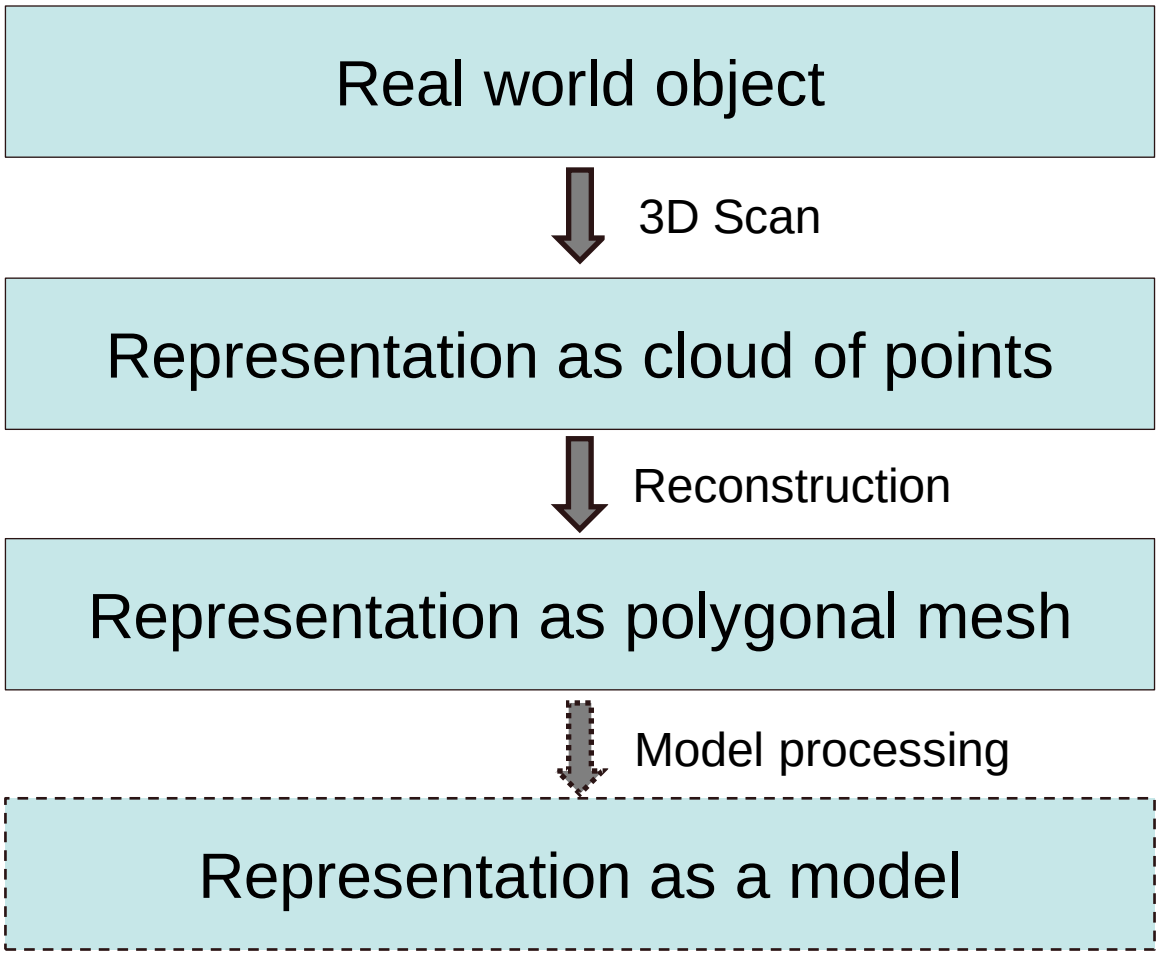
Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

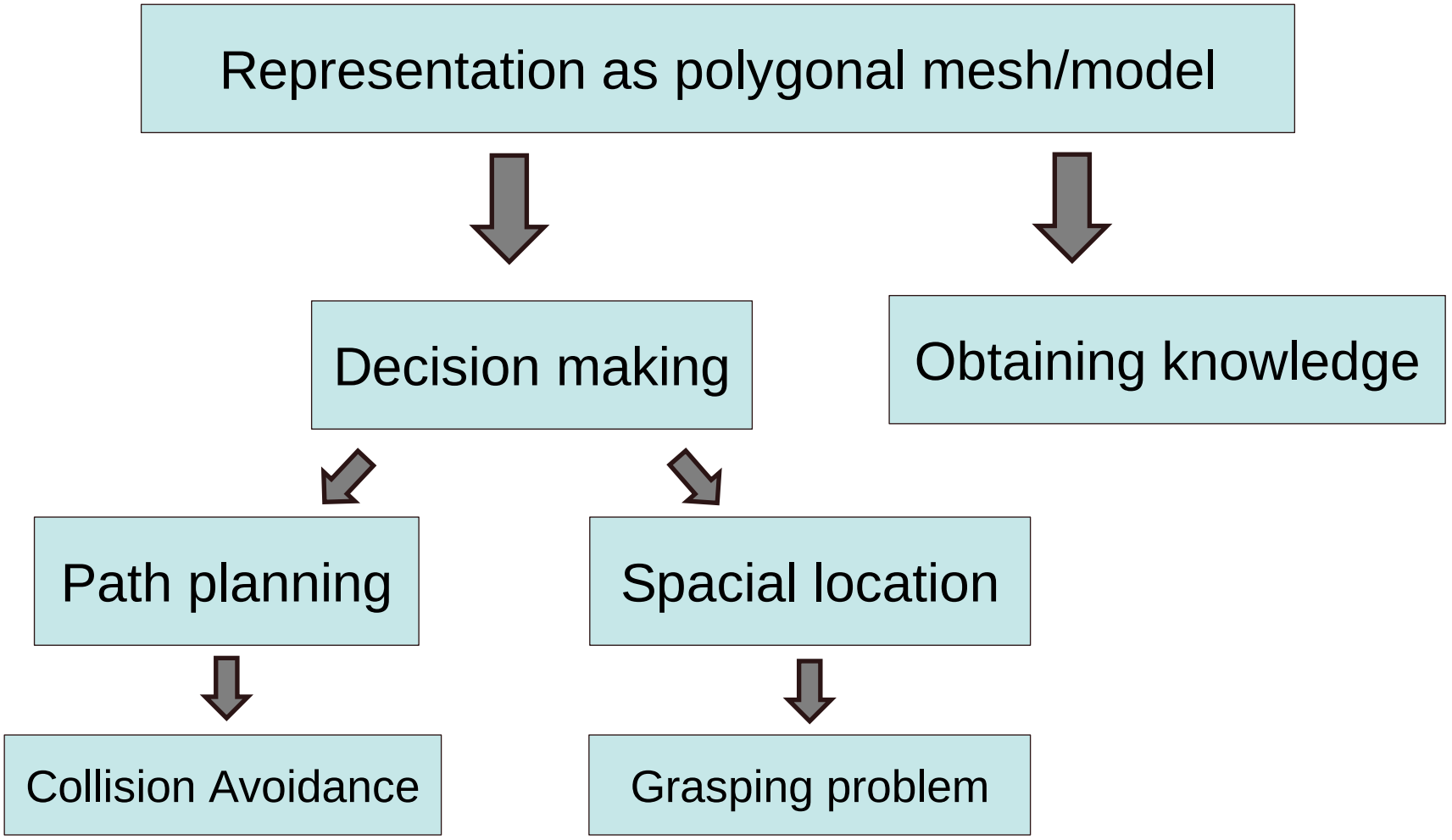
Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

Why is this important



Why is this important

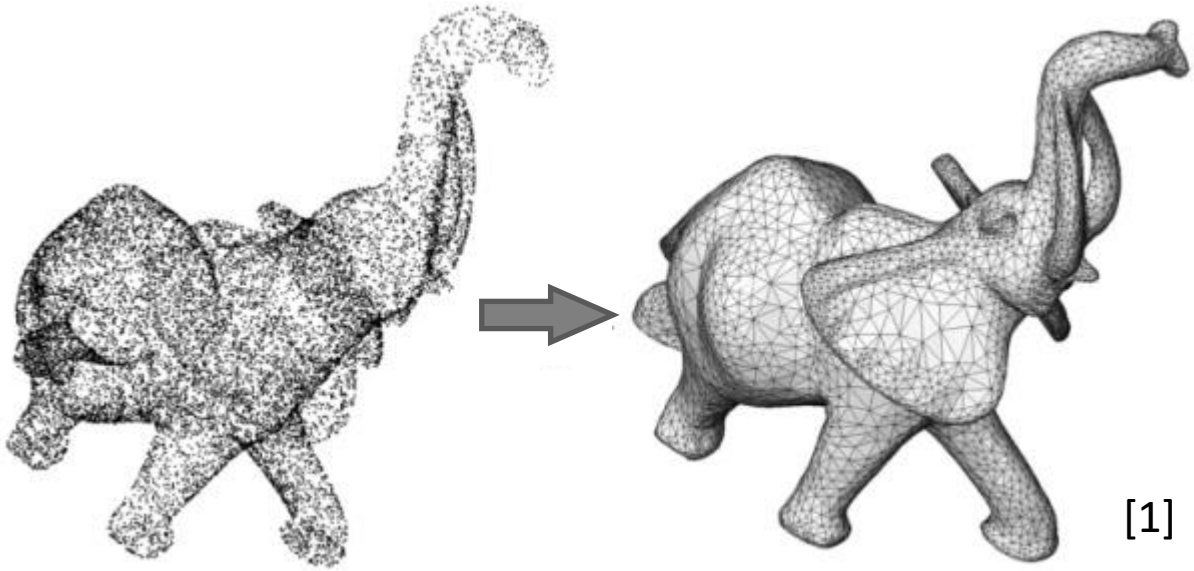


Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

Surface reconstruction

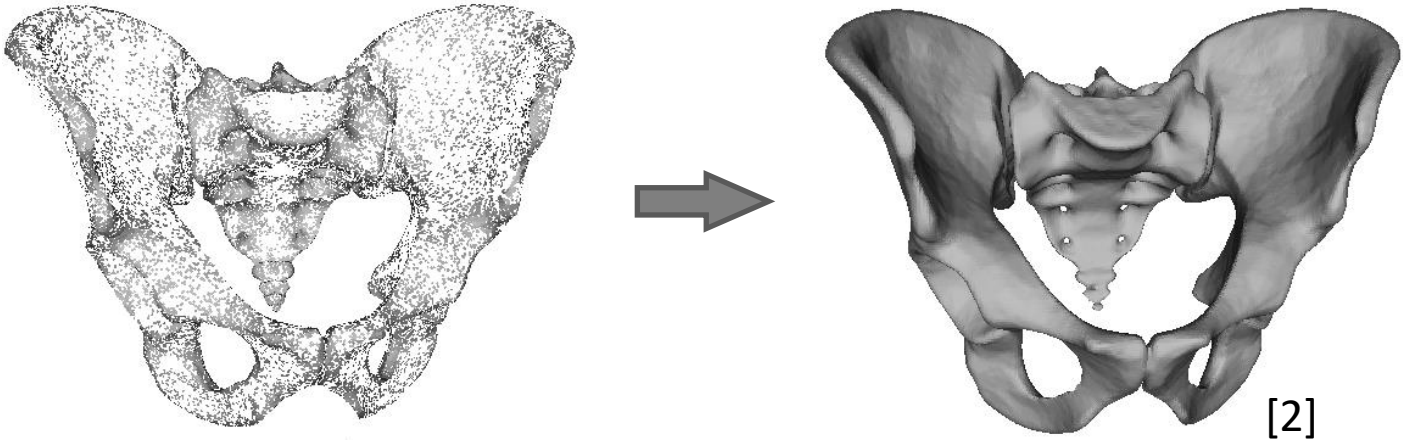
Cloud of points → Surface



[1]

Surface reconstruction

Cloud of points → Surface



[2]

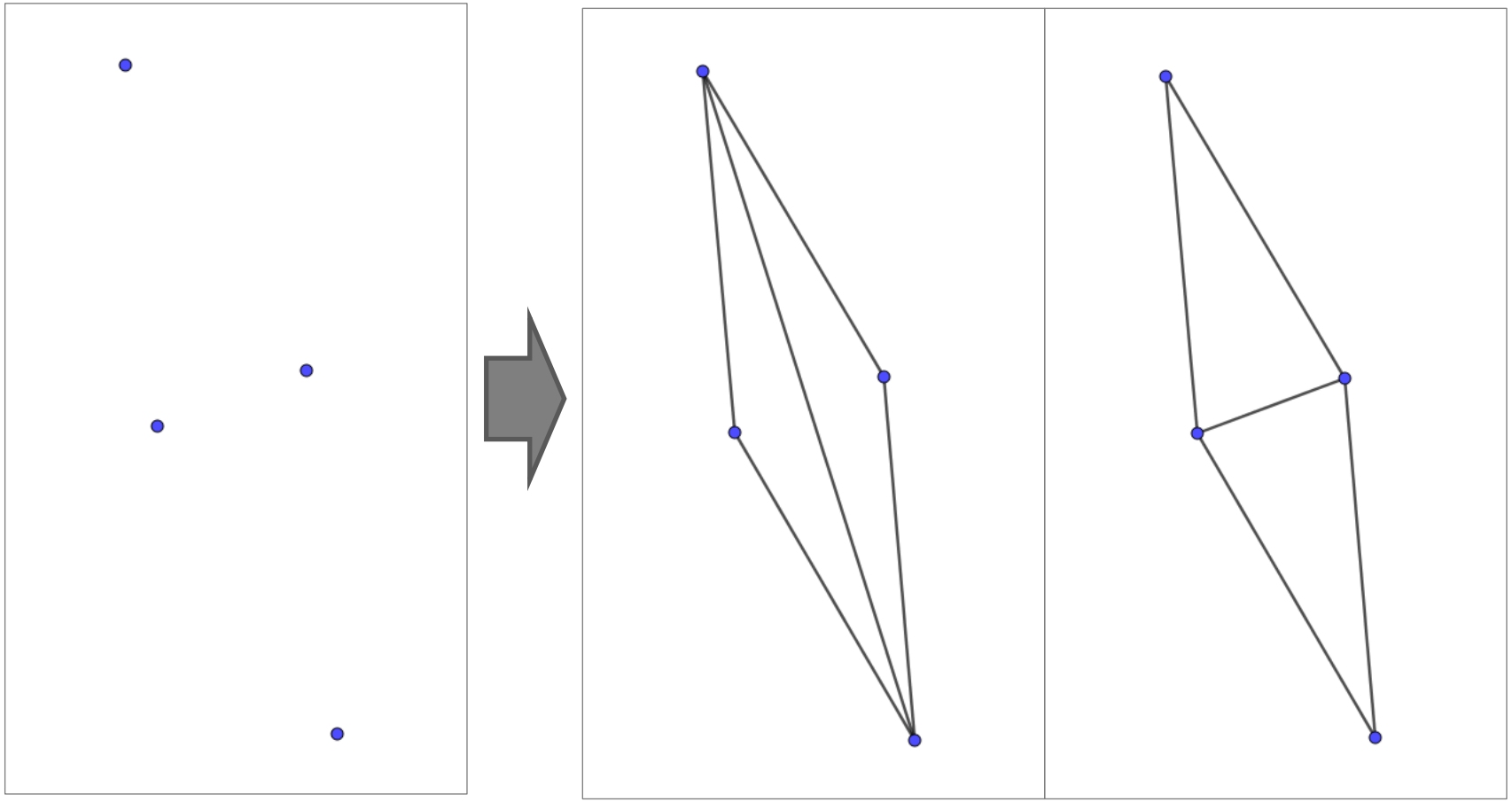
Surface reconstruction

Needs	Solutions
- Solutions to the triangulation problem - Fast enough algorithms	- 3D Delaunay triangulation - Alpha-complexes - Local 2D Delaunay triangulation + incremental mesh algorithm - …

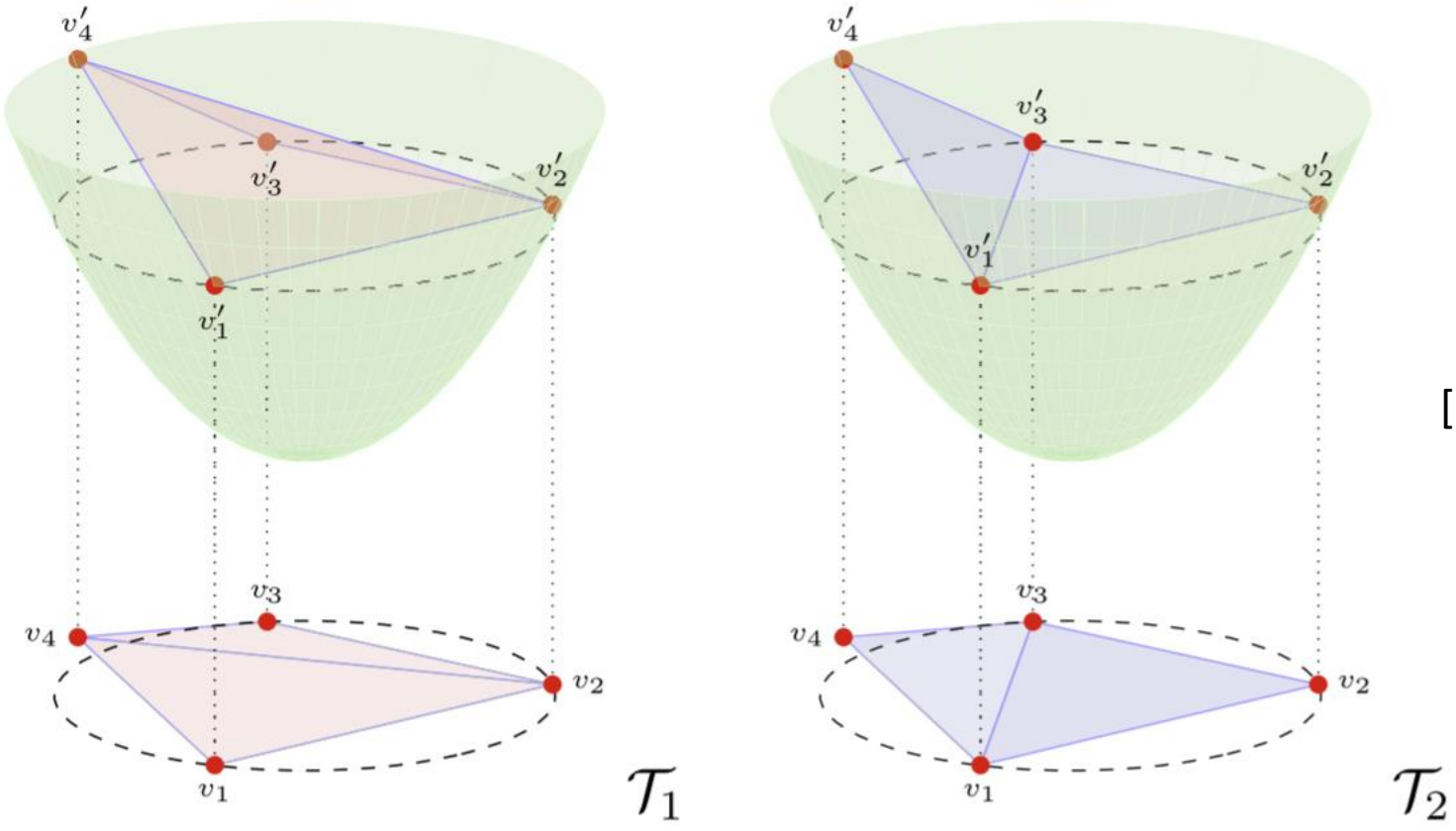
Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

Delaunay triangulation



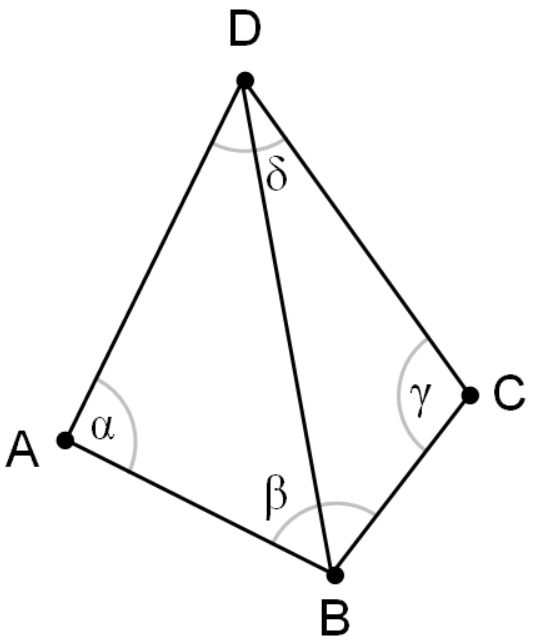
Delaunay triangulation



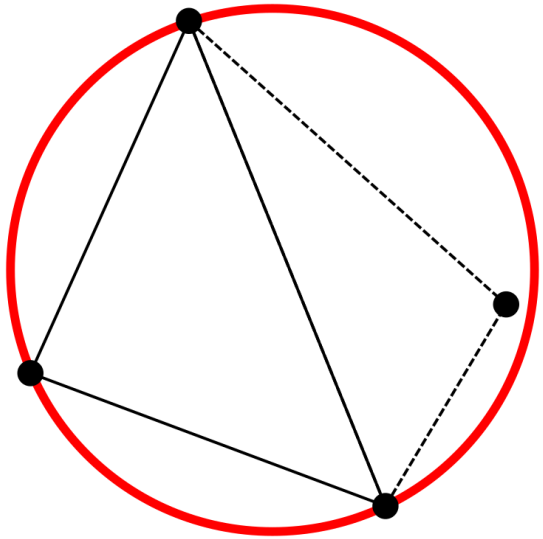
[3]

«Flipping» process

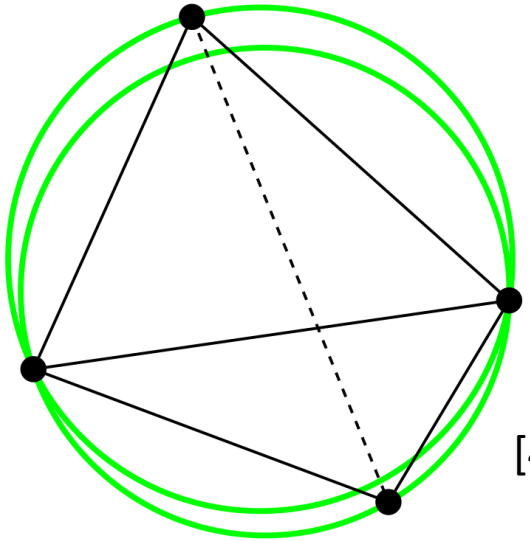
```
Delaunay basic algorithm ( PointSet ){
    graph = randomtriangulation( PointSet );
    while ( !All_triangles_are_valid( graph ) ){
        find invalid pair of triangles and flip it;
    }
    return graph;
}
```



Non-valid triangles



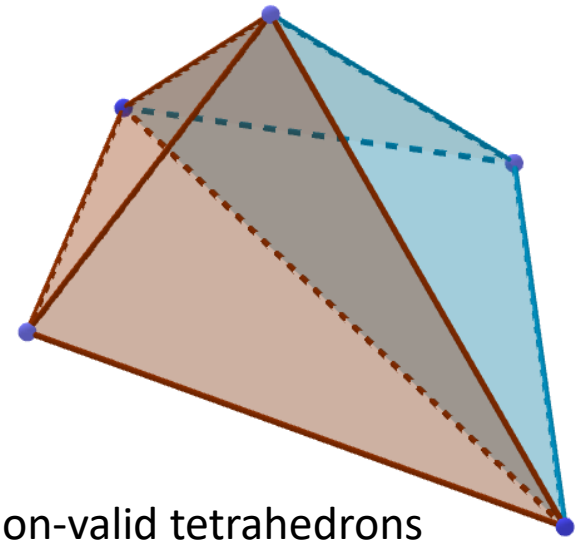
Valid triangles



[4]

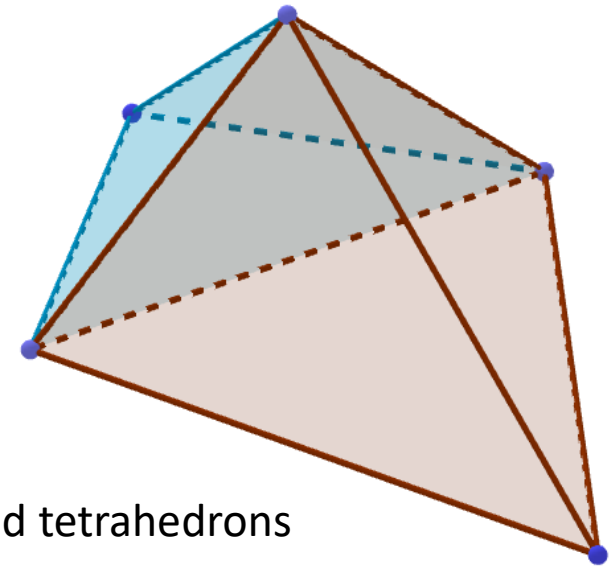
Generalization to N dimensions

```
ND-Delaunay basic algorithm ( PointSet ){
    graph = randomtriangulation( PointSet );
    while ( !All_n-simplex_are_valid( graph ) ){
        find invalid pair of n-simplex and flip it;
    }
    return graph;
}
```



Non-valid tetrahedrons

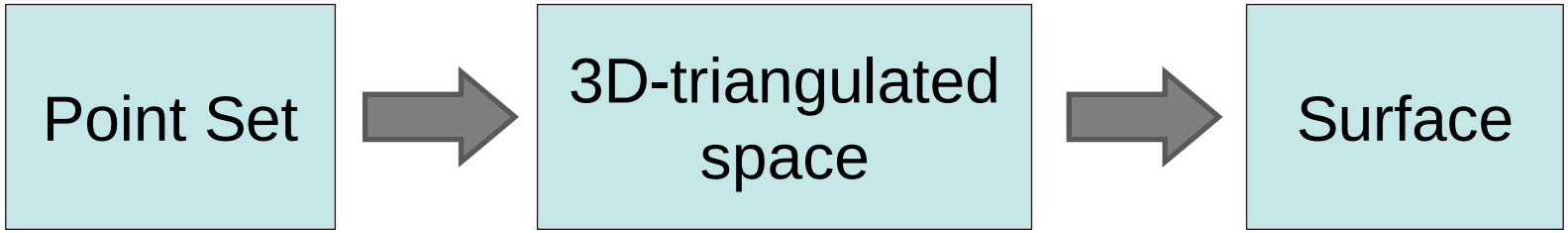
3D Example



Valid tetrahedrons

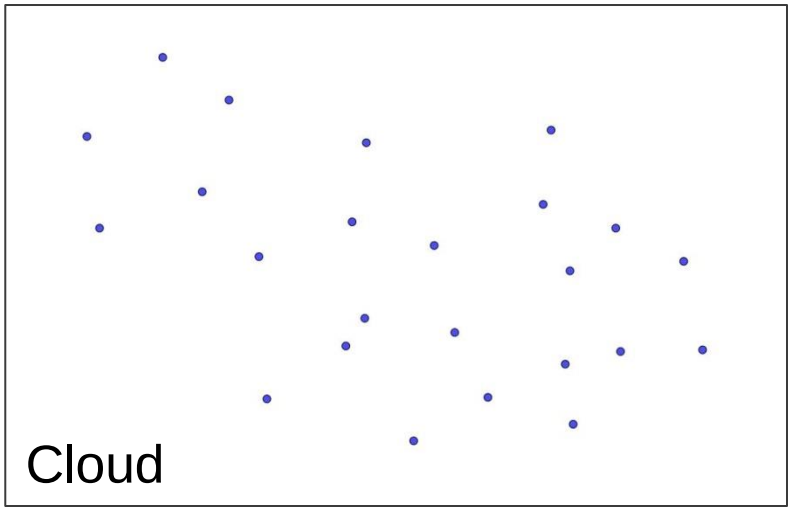
Generic algorithms

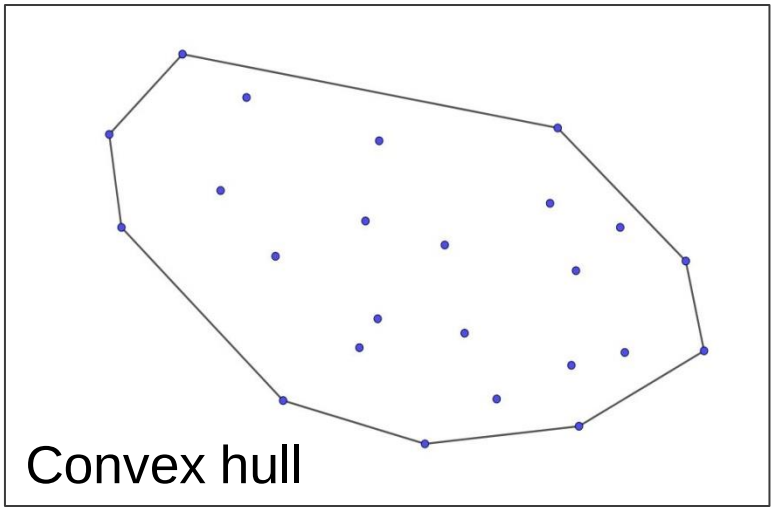
1) Through Delaunay 3D-triangulation

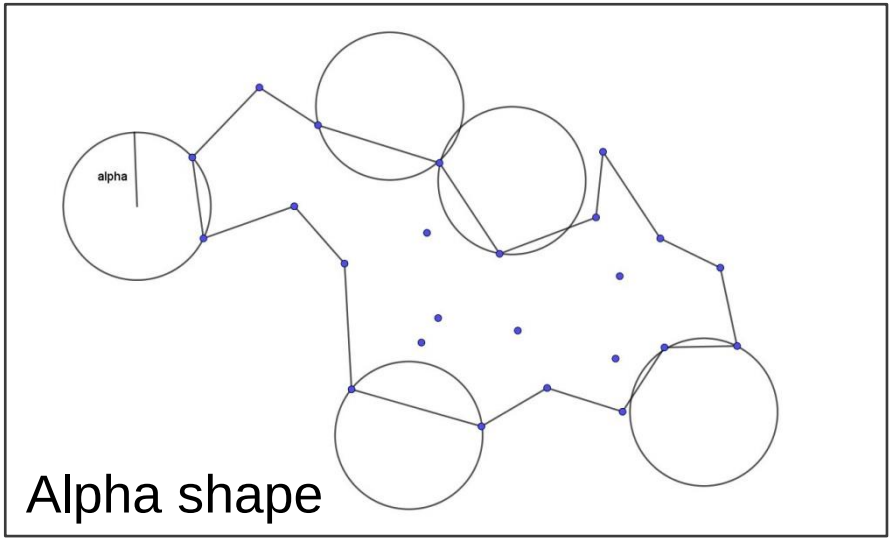


Principal disadvantage: High Complexity

Alpha shapes

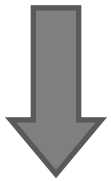






Generalization to N dimensions

2D	Alpha Shape – 1D frontier
ND	Alpha Shape – (N-1)D polytope



3D	Alpha Shape – 2D Polygonal mesh

Generic algorithms

1) Through 3D alpha shape generation

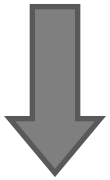
Principal disadvantage: ¿Which alpha do we choose?

Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

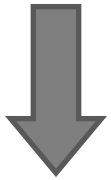
Fast reconstruction

Alpha shapes



Mesh-growing algorithm through Gabriel-2 criterion

Delaunay triangulation



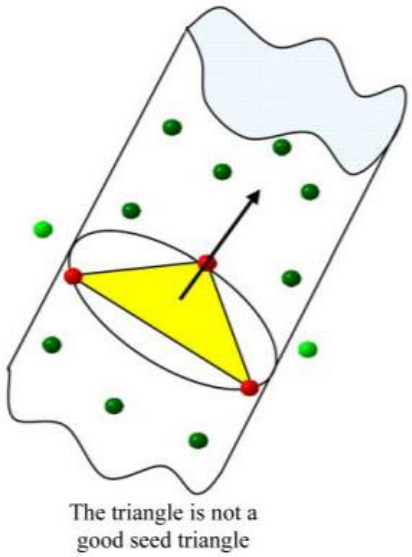
Divide-and-conquer approximation of Delaunay applied to locally flat surfaces

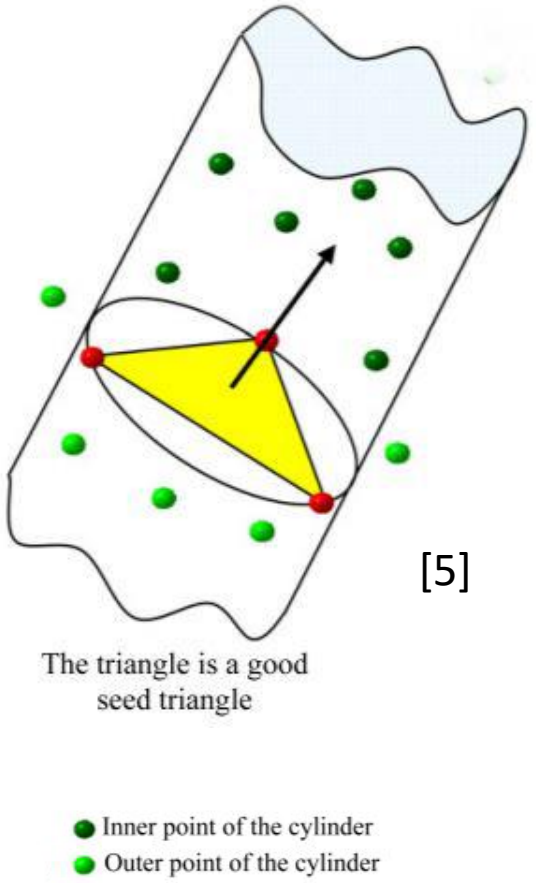
G2C-based algorithm

```
G2C_triangulation(Pset){
  mesh = seed(Pset);
  while(frontier_exists){
    search_candidates;
    mesh += candidates;
  }
  return mesh;
}
```

G2C-based algorithm

```
G2C_triangulation(Pset){
   mesh = seed(Pset);
   while(frontier_exists){
      search_candidates;
      mesh += candidates;
   }
   return mesh;
}
```

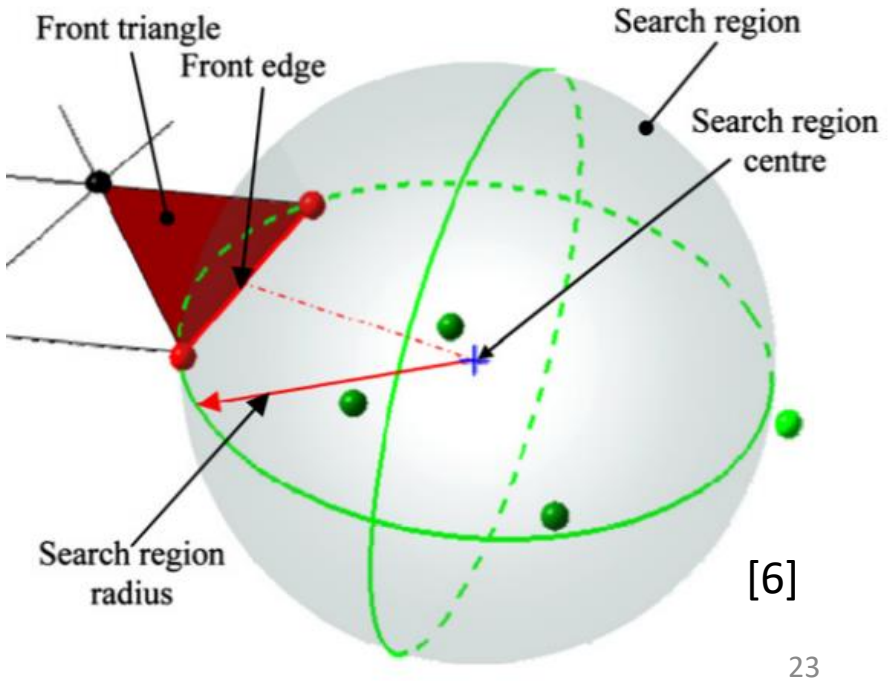




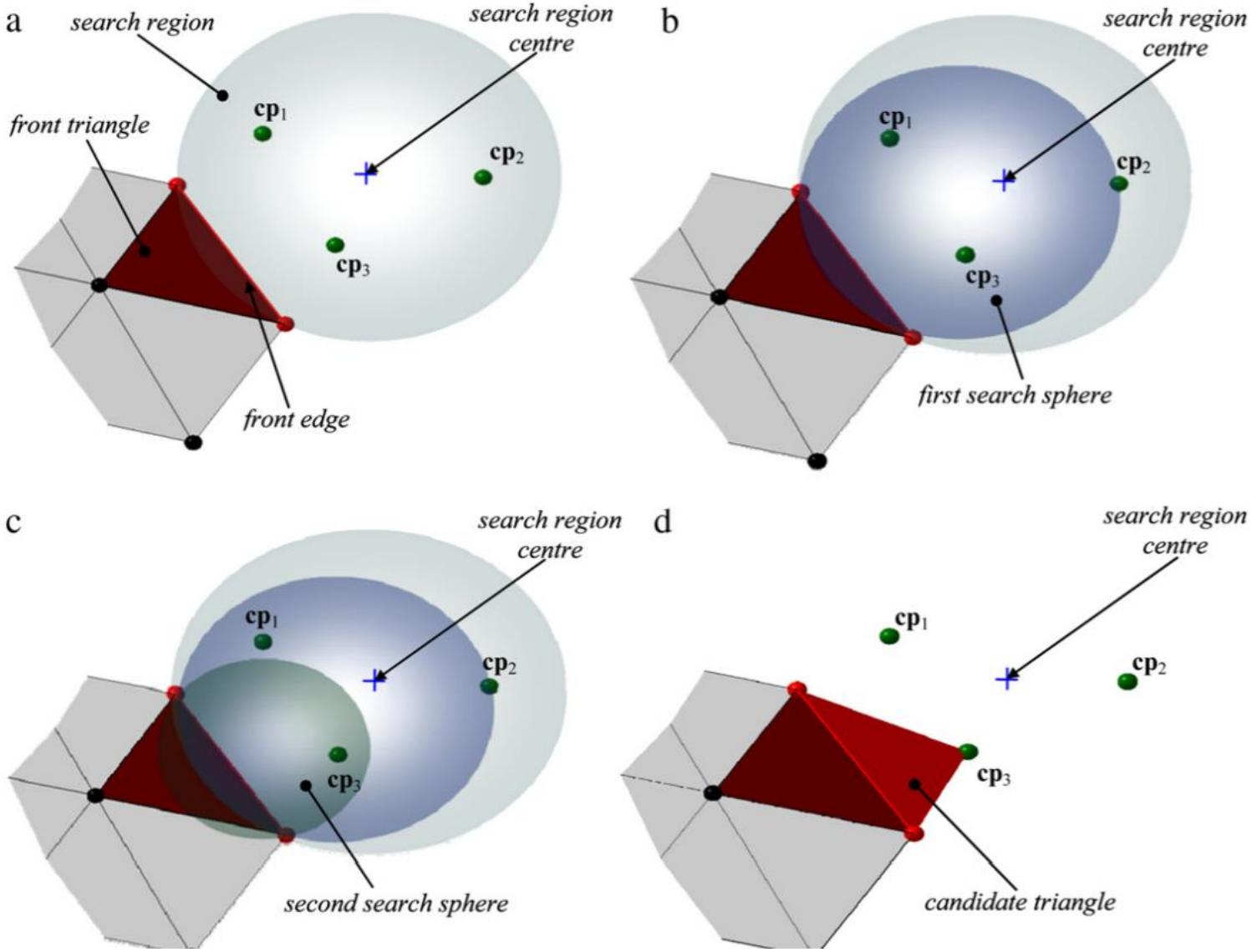
[5]

G2C-based algorithm

```
G2C_triangulation(Pset){
   mesh = seed(Pset);
   while(frontier_exists){
      search_candidates;
      mesh += candidates;
   }
   return mesh;
}
```



[6]


a
search region
search region centre
front triangle
cp1
cp2
cp3
front edge
b
search region centre
cp1
cp2
cp3
first search sphere
c
search region centre
cp1
cp2
cp3
second search sphere
d
search region centre
cp1
cp2
cp3
candidate triangle

[7]

G2C-based algorithm

Advantages	Disadvantages
Good aproximation to Delaunay in simple, regularly-sampled surfaces Good aproximation to alpha-complex in any surface	Static model Really sensible to noise

D&C locally-flattened Delaunay

```
LFD-triangulation(Pset){
  divide set into subsets;
  normalize the subsets;
  for s in subsets{
    calculate average plane;
    project s in plane;
    Delaunay triangulation in s;
  }
  unite subsets into surfaces;
}
```

D&C locally-flattened Delaunay

Advantages	Disadvantages
Good aproximation to Delaunay in all surfaces Easily modifyable to be incremental / dynamic Not so sensible to noise	Can have problems with more complicated surfaces

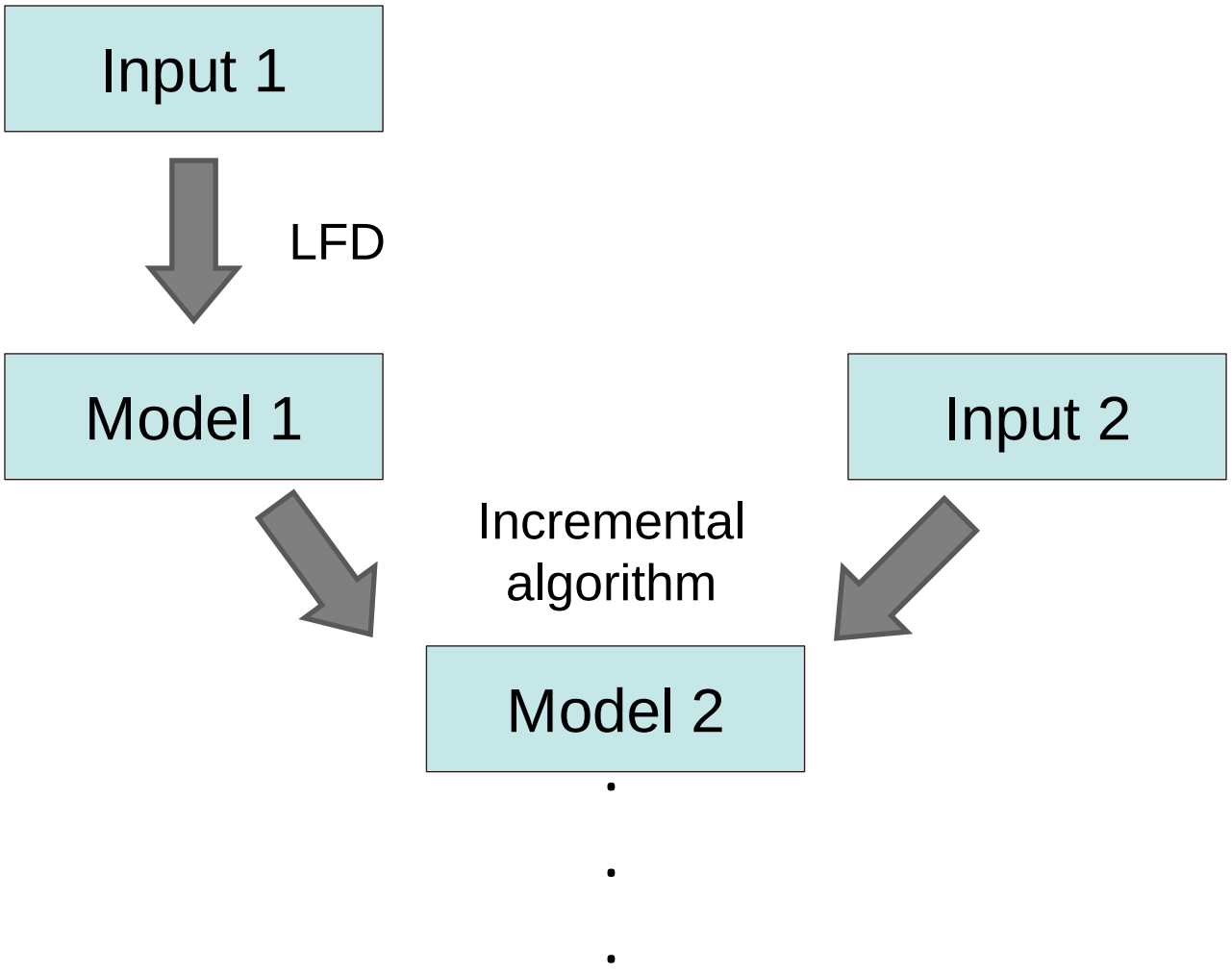
Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

Incremental reconstruction

- Reconstruction of surfaces from more than one data input.
- Example: frames of a video taken by a moving camera.

Incremental reconstruction



Index

- Why is this important
- Surface reconstruction
- Generic algorithms
- Fast reconstruction
- Incremental reconstruction
- Some results (videos)

Images

[0] – Michel Angelo's David 3d model by iraklichko -
[1] – CGAL 5.0 user manual – Poisson surface reconstruction - https://doc.cgal.org/latest/Poisson_surface_reconstruction_3/index.html
[2] – Reconstruction of Solid Models from Oriented Point Sets, John Hopkins University – Copyright 2005, Michael Kazhdan - http://www.cs.jhu.edu/~misha/Code/Reconstruct3D/
[3] – Long Chen, Michael Holst – Efficient mesh optimization schemes based on optimal Delaunay triangulations - 2010
[4] – Wikipedia- https://en.wikipedia.org/wiki/Delaunay_triangulation
[5, 6, 7] – Luca Di Angelo, Paolo Di Stefano, Luigi Giaccari -
A new mesh-growing algorithm for fast surface reconstruction - 2011

Bibliography

- Yuchen He, Martin Huska, Sung Ha Kang and Hao Liu – Fast algorithms for surface reconstruction from point cloud
- Zoltan Csaba Marton, Radu Bogdan Rusu, Michael Beetz – On surface reconstruction methods for large and noisy point clouds
- Luca Di Angelo, Paolo Di Stefano, Luigi Giaccari – A new mesh-growing algorithm for fast surface reconstruction – 2011