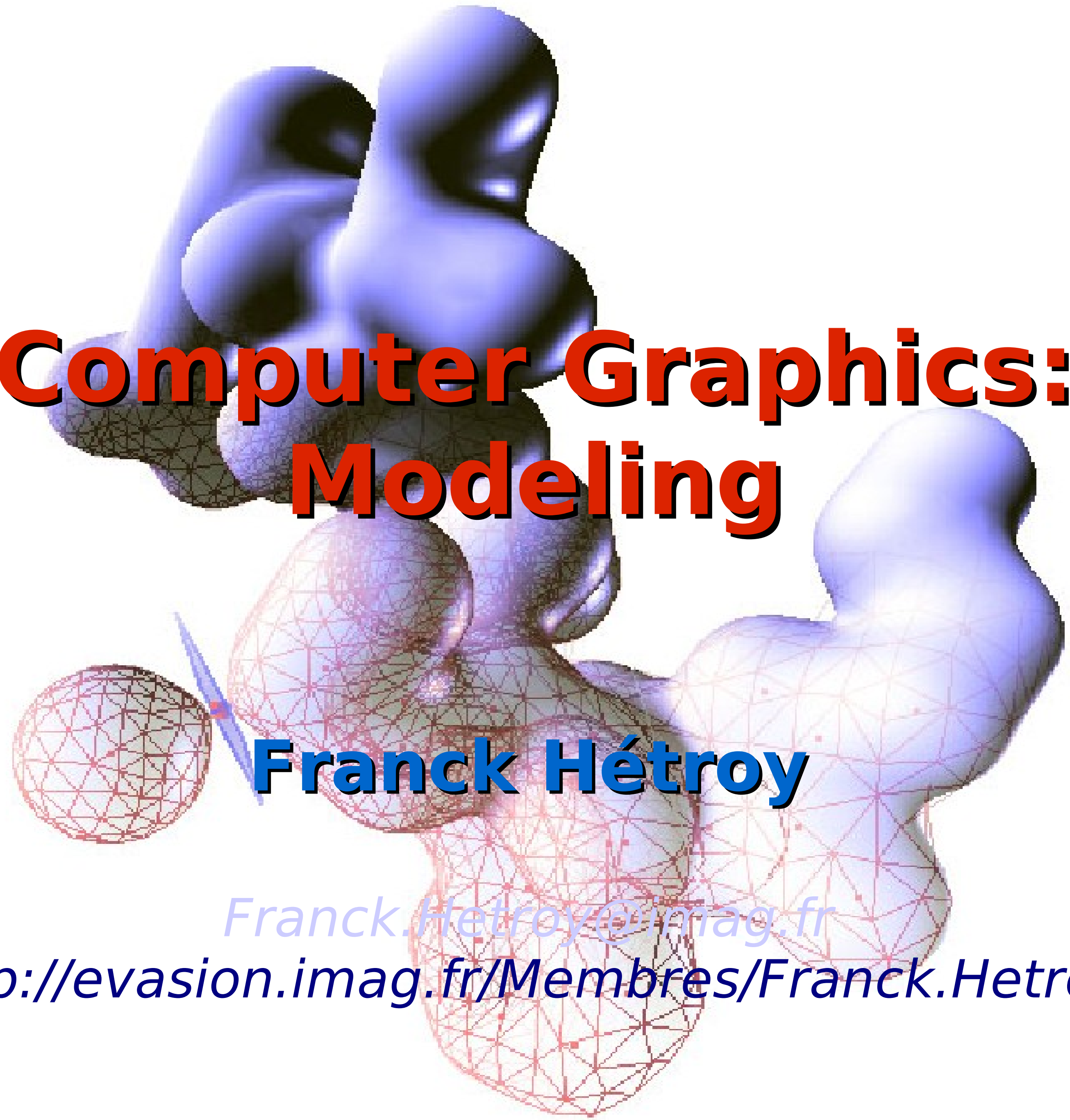

Computer Graphics: Modeling

Franck Hétroy

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Today's planning

1. Problem solving
   - 1 hour debate, 4x10 minutes presentation
- Pros and cons of surface representations
- Volume representations

Teams (tentative)

- Team 1:

  Reynald Arnerin, Azim Azma, Laurent Belcour, Robert Conceivo Da Silva, (Adrien Gomez Espana Pecker)

- Team 2:

  Nicolas Esteves, Sylvain Guglielmi, (Juan Alberto Lahera ~~Perez,) Mohamed~~ Riadh Trad, Xue Bing

- Team 3:

  Pierre Arnaud, Varun Raj Kompella, Anja Marx, Jorge Pena, Thibault Serot

- Team 4:

  Antoine Bautin, (Adrien Brilhault,) Noura Faraj, Alfonso Garcia, Stefano Sclaverano

Today's planning

- ~~Problem solvi~~ng
  - ~~1 hour debate, 4x10 minutes pres~~entation
- Pros and cons of surface representations
- Volume representations

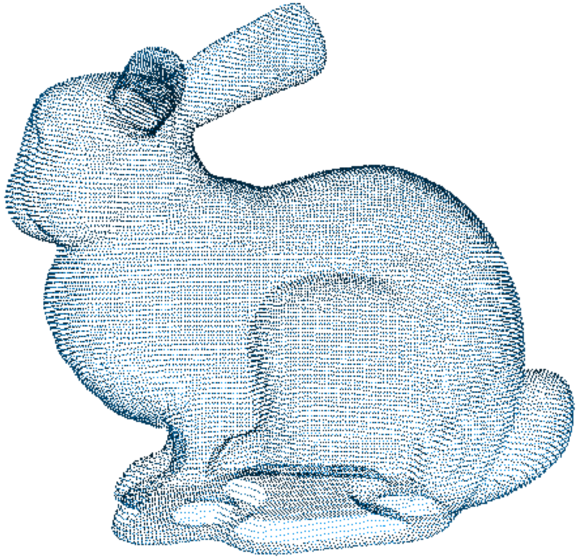
Pros and cons of surface representations

1. Point sets
2. Meshes
3. Parametric surfaces
4. Subdivision surfaces
5. Implicit surfaces

Point sets

- Result of scanner acquisition
- Also image-based modeling
- Main advantages:
  - "Natural" representation
  - Simple and cheap to display
- Main drawbacks:
  - No connectivity info: underlying shape = ?
  - Tedious to edit

NextEngine scanner:
available here!



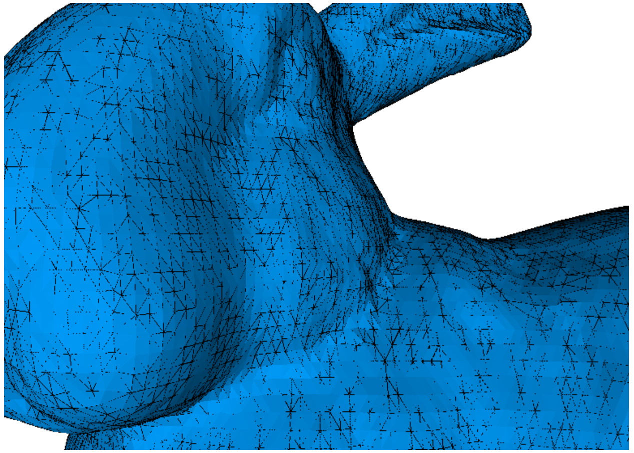
Too simple ?

- If nb of points too low: holes
- However:
  - Currently scanned models have up to several millions points
  - Mesh reconstruction is then time-consuming
  - Memory to store the mesh also a problem (number of faces ~ 2 x number of points)
  - Each face projects onto only one or two pixels !
- That is why surface representation by a point set is more and more used and studied

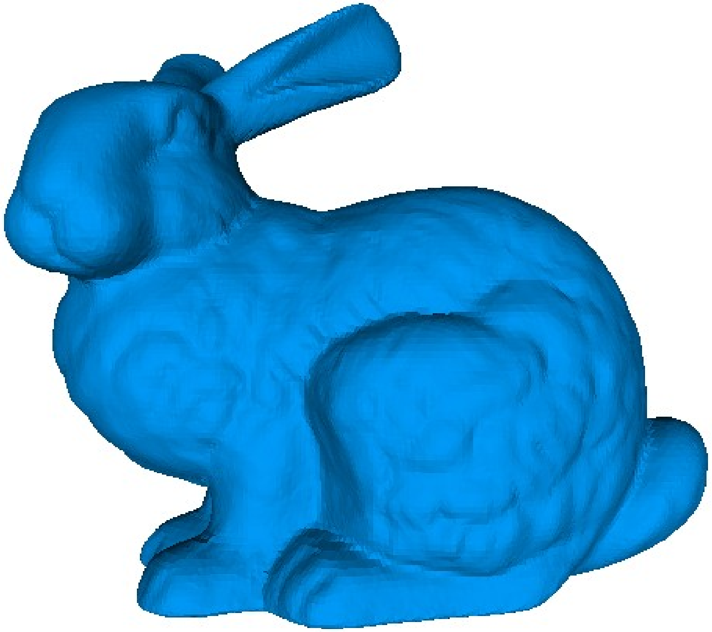
Pros and cons of surface representations

1. ~~Point sets~~
2. Meshes
3. Parametric surfaces
4. Subdivision surfaces
5. Implicit surfaces

Meshes



- Main advantage: easy display
- Main drawback: tedious to edit
- Represent continuous piecewise linear surfaces
- Encode
  - (Approximate) geometry
    - OK for planar shapes (CAD)
    - Bad for curved shapes
  - Topology



Pros and cons of surface representations

1. ~~Point sets~~
2. ~~Meshes~~
3. Parametric surfaces
4. Subdivision surfaces
5. Implicit surfaces

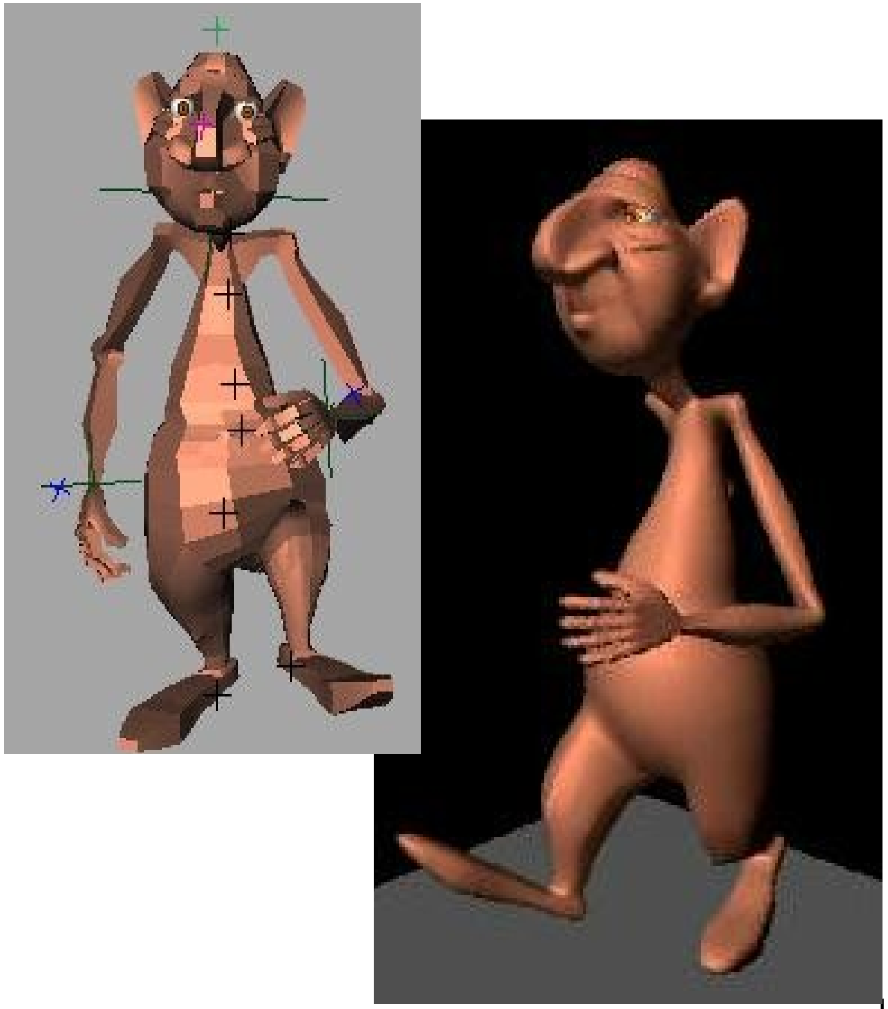
Why do we need Smooth Surfaces ?

Meshes

- Explicit enumeration of faces
- Many required to be smooth!
- Smooth deformation???

Smooth surfaces

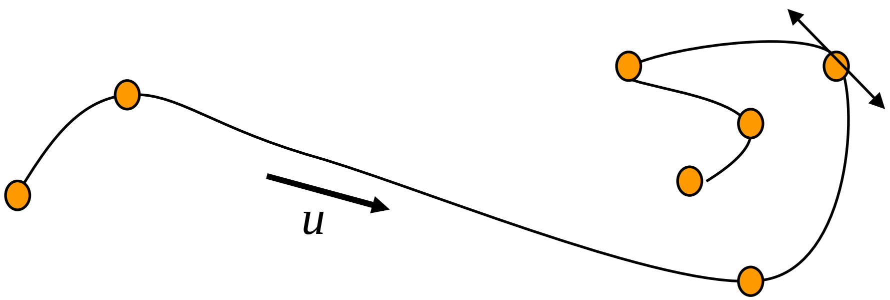
- Compact representation
- Will remain smooth
  - After zooming
  - After any deformation!



Parametric curves and surfaces

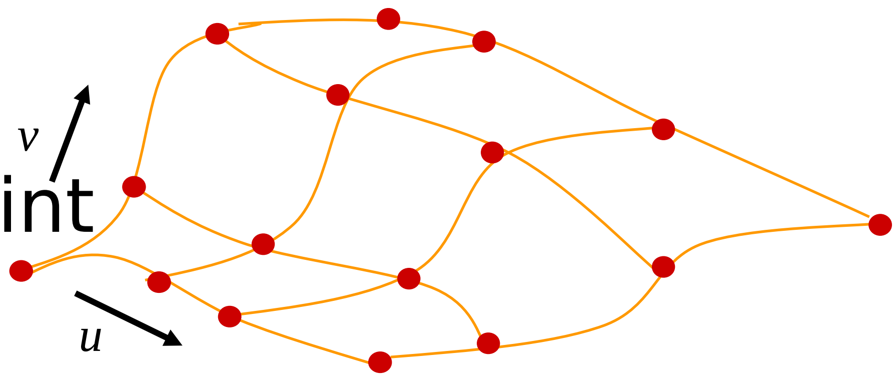
Defined by a parametric equation

- Curve: *C(u)*
- Surface: *S(u,v)*



Advantages

- Easy to compute point
- Easy to discretize
- Parametrization



Pros and cons of surface representations

1. ~~Point sets~~
2. ~~Meshes~~
3. ~~Parametric surfaces~~
4. Subdivision surfaces
5. Implicit surfaces

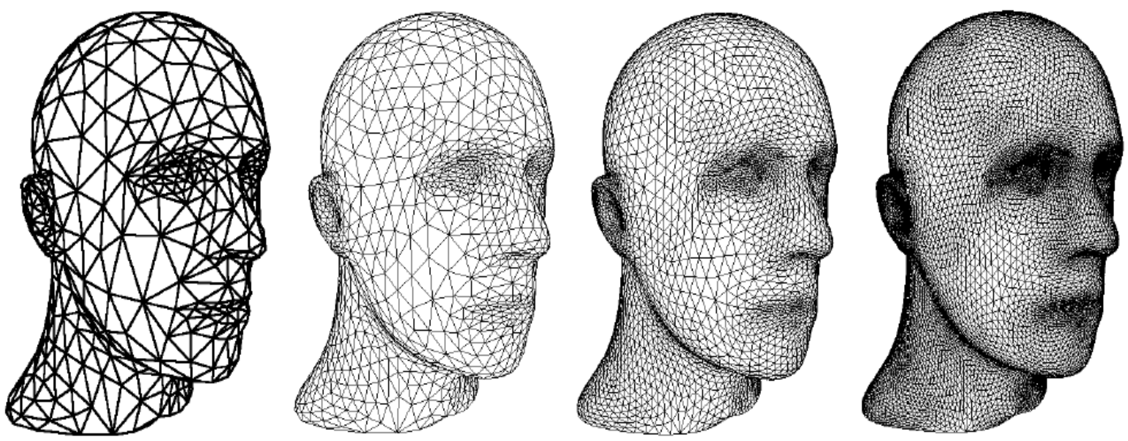
Subdivision Surfaces

Benefits

- Arbitrary topology & geometry (branching)
- Approximation at several levels of detail (LODs)

Drawback: No parameterization, some unexpected results

Loop



Extension to multi-resolution surfaces : Based on

Pros and cons of surface representations

1. ~~Point sets~~
2. ~~Meshes~~
3. ~~Parametric surfaces~~
4. ~~Subdivision surfaces~~
5. Implicit surfaces

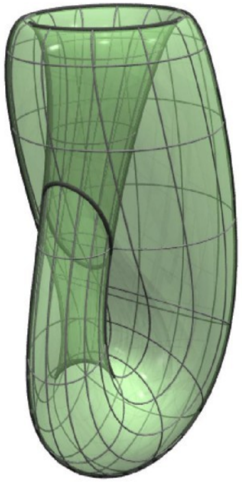
Drawbacks of Boundary Representations

- Complex shapes with splines ?
  - Branches ?
  - Arbitrary topological genus ?

  Partly solved by subdivision surfaces

- Surrounding a volume?
  - Avoid Klein bottles!
  - Prevent self-intersections

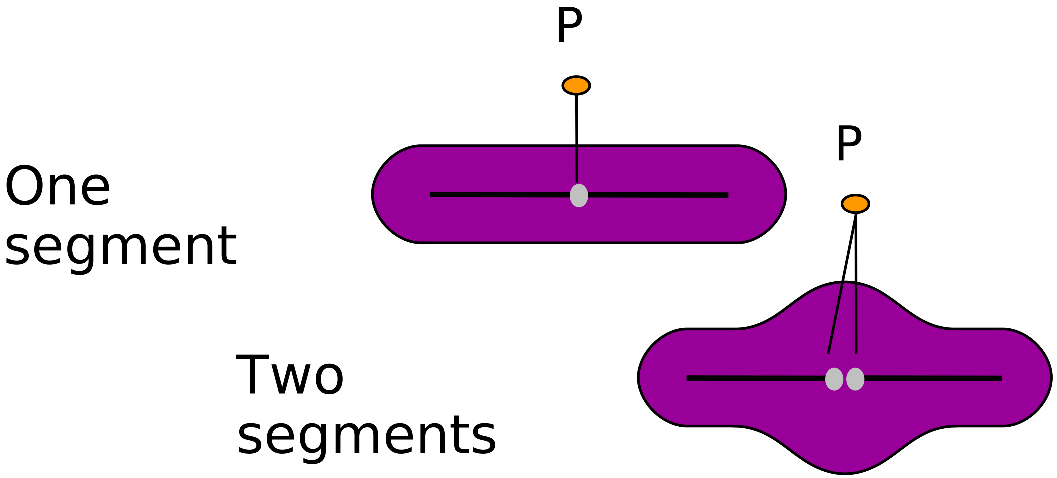
  Make them impossible?

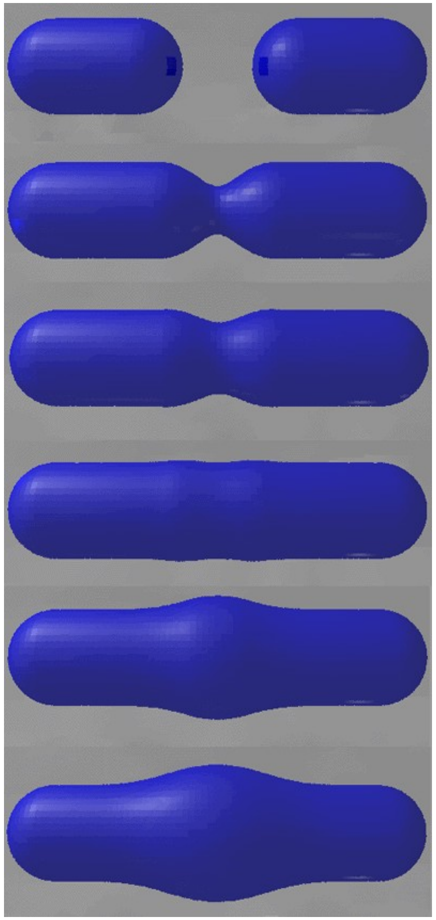


Unwanted Bulges?

Distance surfaces

- Distance to the closest point on S_i
- The shape changes if S_i is divided
- 3D bulge at all joints!



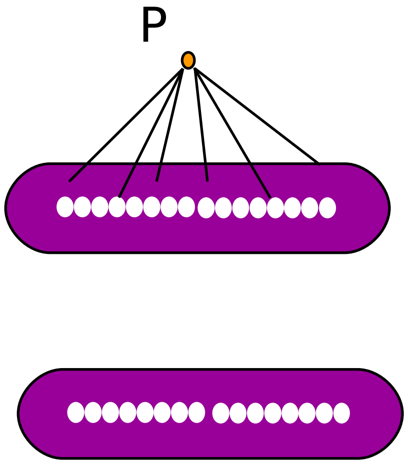


Avoid Unwanted Bulges?

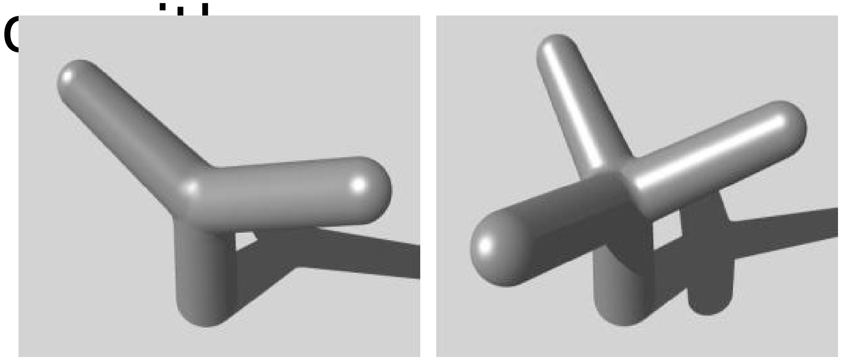
Convolution surfaces *[Bloomenthal Shoemake 91]*

- Integral along Si on point contributions

$$F(S, p) = \int_{s \in S} f(s, p)\,ds$$

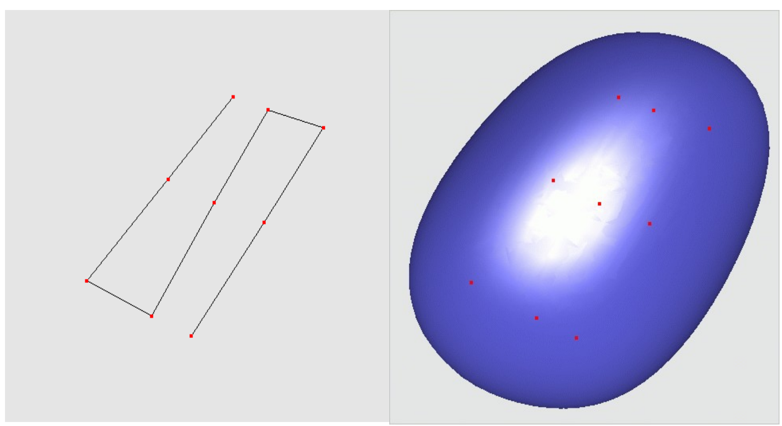


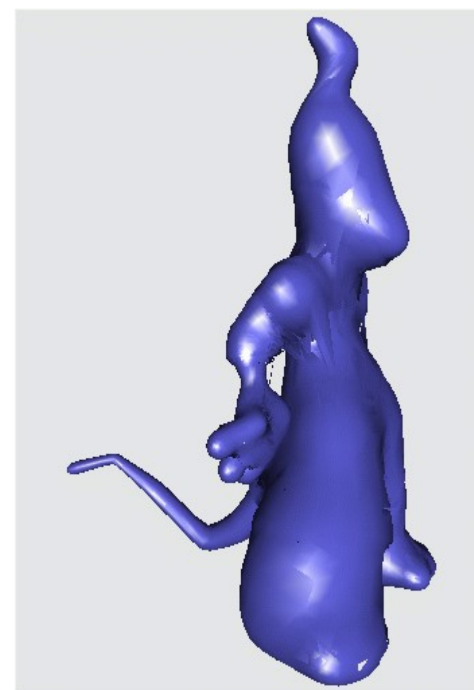
= convolution of the skeleto… kernel



Unwanded Blending problem

- Primitives blend according to their distance!





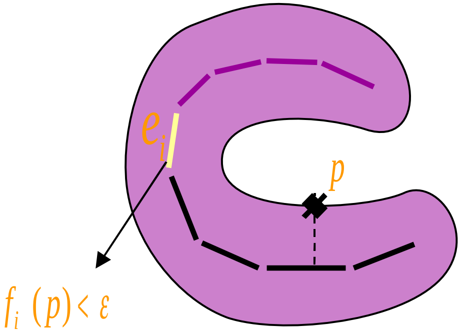
Solutions to Unwanded Blending

Idea: “blending graph” expressing the shape’s topology

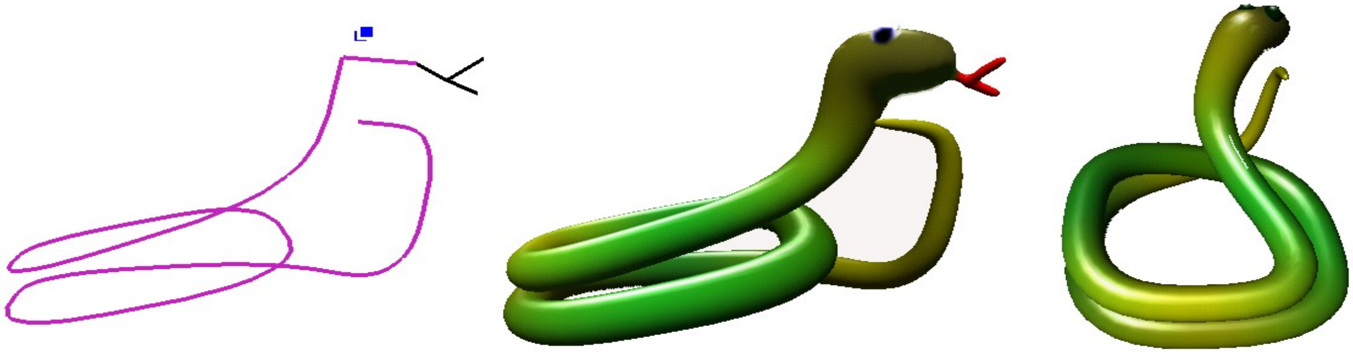
- *[Guy Wyvill 1995]*

  Find the main primitive

  Add its immediate neighbours



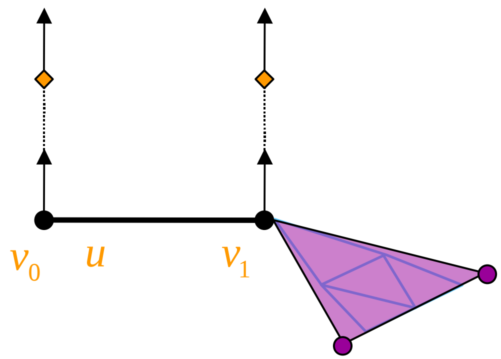
- *[Cani Hornus 2001]*
  - blend until the contribution is small enough

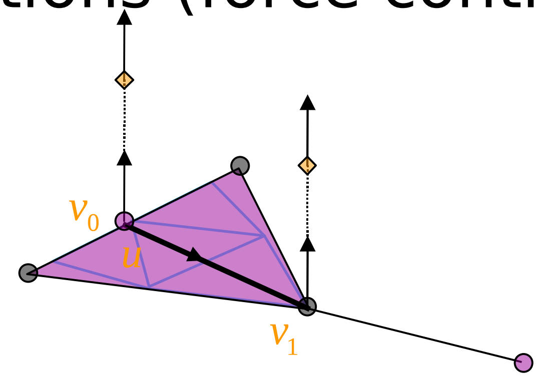


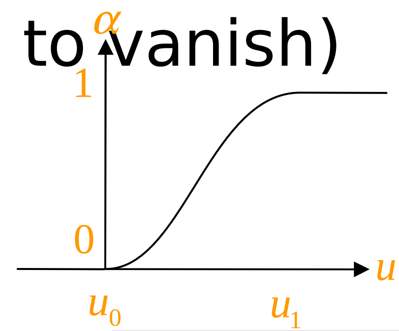
Solutions to Unwanded Blending

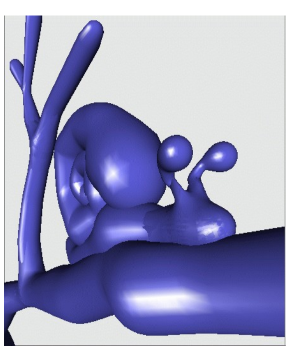
Idea: “blending graph” expressing the shape’s topology

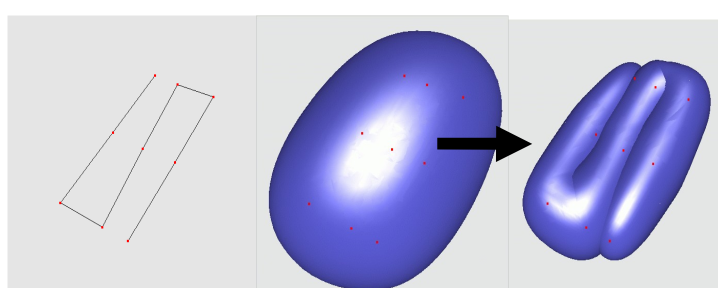
- *[Angelidis Cani 2002]*
  - decay functions (force contributions to vanish)

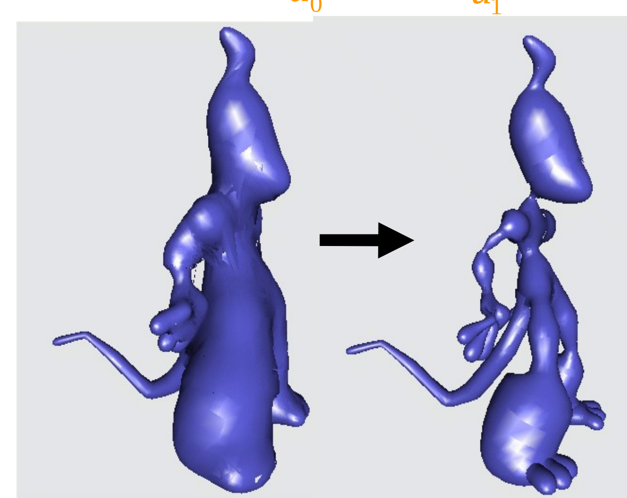










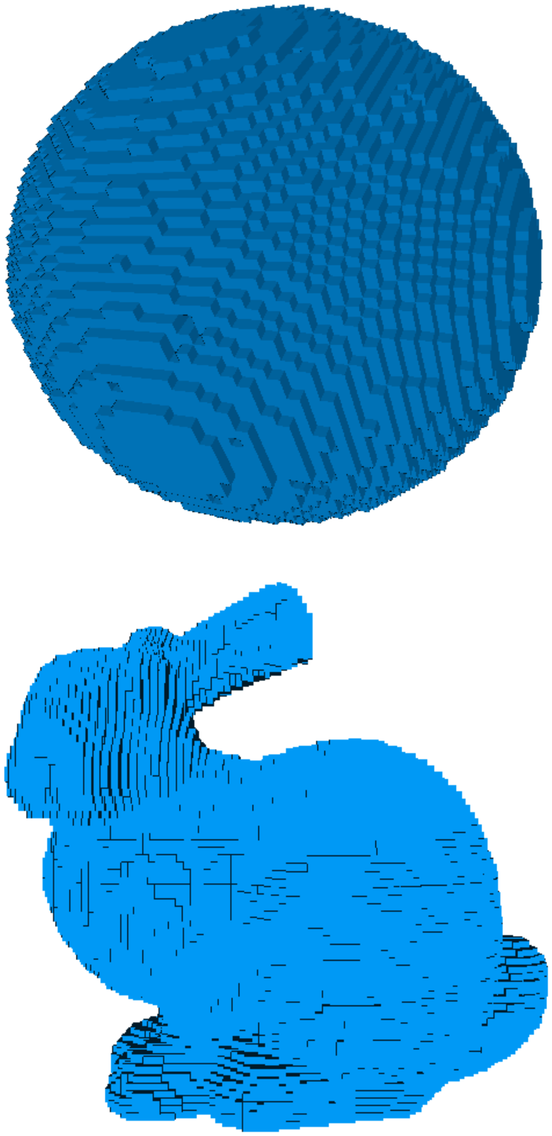


Today's planning

- ~~Problem solving~~
  - ~~1 hour debate, 4x10 minutes presentation~~
- ~~Pros and cons of surface representations~~
- Volume representations

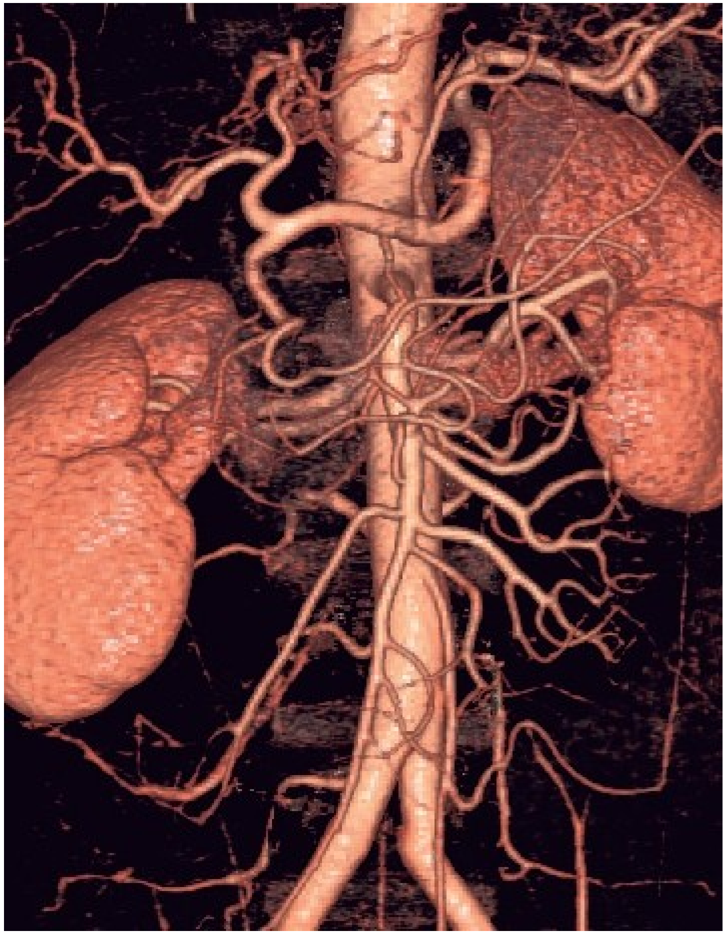
Voxels

- Volumetric representation
- (Regularly) discretize the 3D space and only keep elements inside the object
- 2D : pixel = PICTure ELement
- 3D : voxel = VOlume ELement
- And also: surfel (surface), texel (texture), …



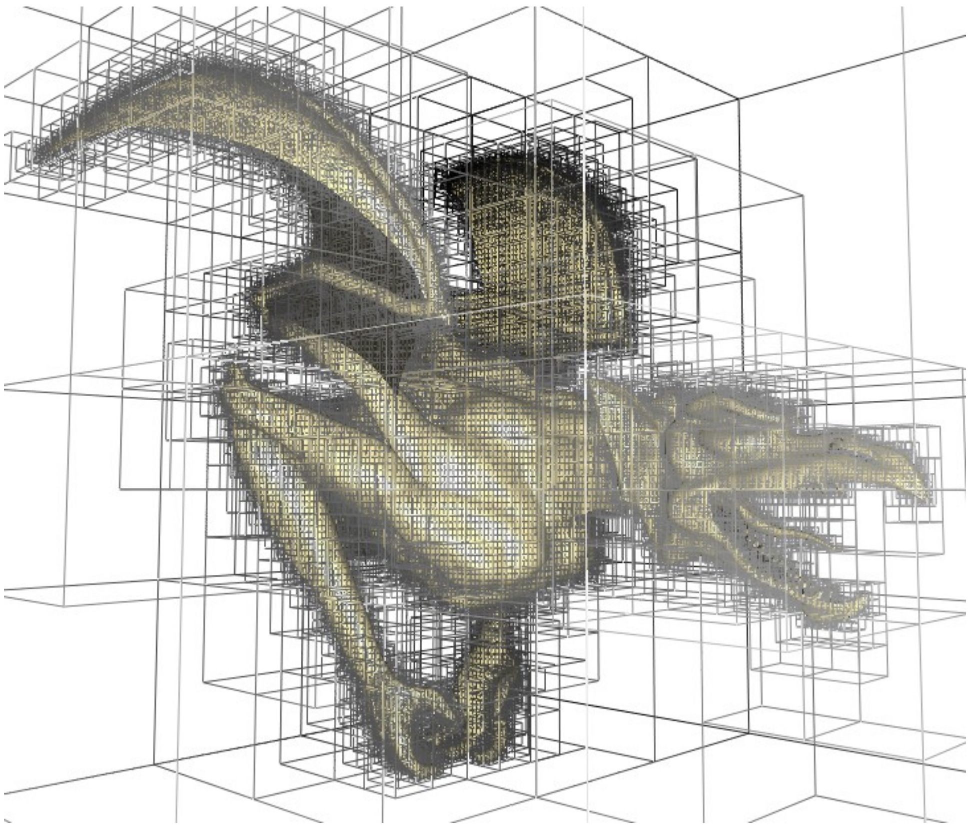
Voxel set acquisition

- Using a function sampled on a grid
  - Numerical simulation
- Tomographic reconstruction (CT scan)
  - Medical area
- Depending on the acquisition/application, voxels contain scalar values (function, density, color, ...)



Octree

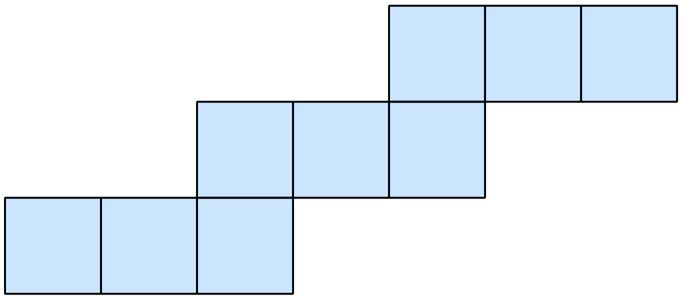
- Voxel hierarchy
- Saves memory
- Interesting for:
  - Spatial queries
  - Collision detection
  - Hidden surface removal ("view frustrum culling")

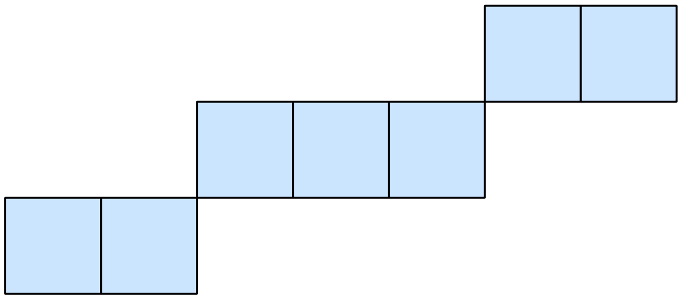


Courtesy S. Lefebvre

An introduction to discrete geometry

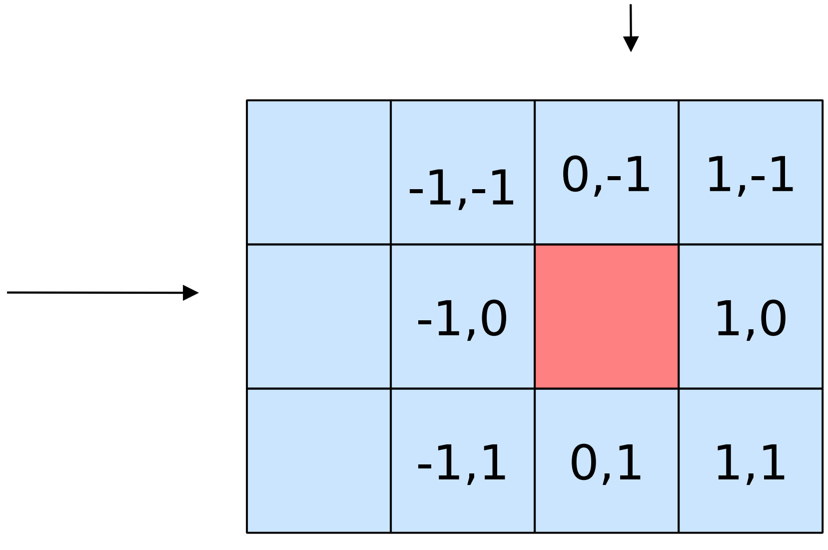
- Theoretical/Mathematical study of **regular** 2D/3D (simple) objects
  - Sampled on a grid
  - Object = point, line, plane
- How to define what is a line of voxels ?
- Adapted algorithms





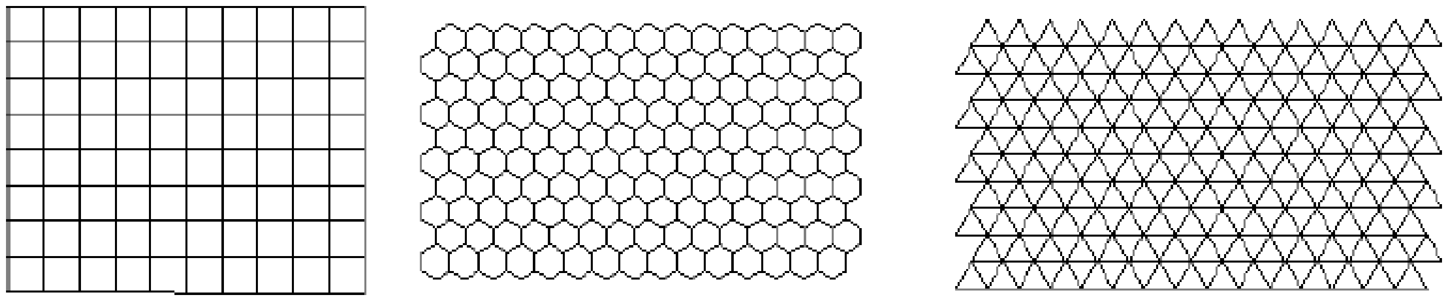
Why a regular grid

- Simple topology
- Easy address to a cell: coordinates
- Easy access from a cell to its neighbors
- Physical reality (sensors)



Cell

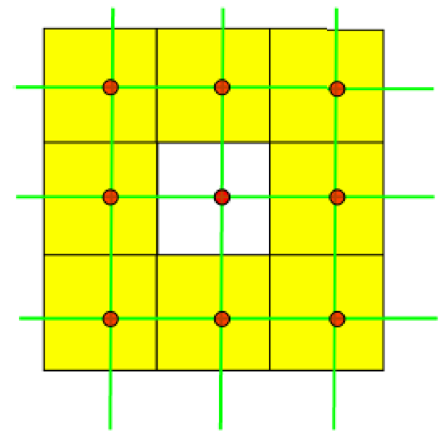
- Usually a convex polygon/polyhedron
- Regular
- The 3 principal cases: square/cube, hexagon/hexahedron, triangle/tetrahedron



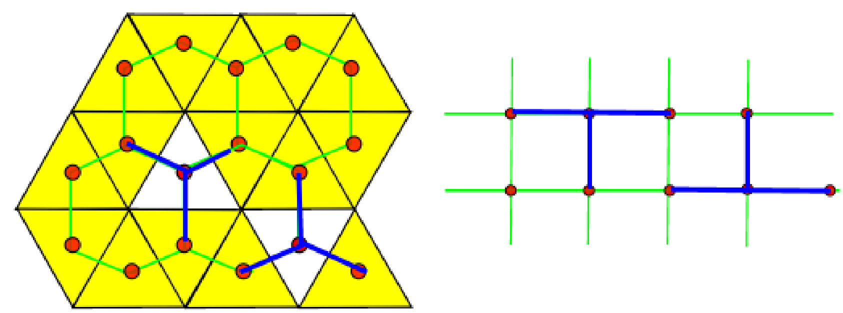
Courtesy D. Coeurjolly & I. Sivignon

Advantage of squares/cubes

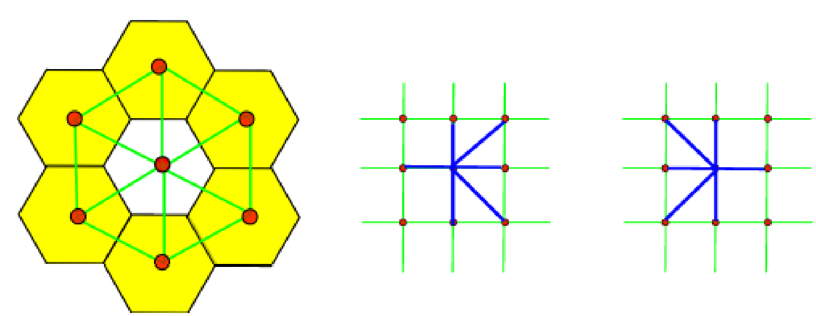
- Square:
  - 4 neighbors
  - 1 configuration



- Triangle:
  - 3 neighbors
  - 2 configurations



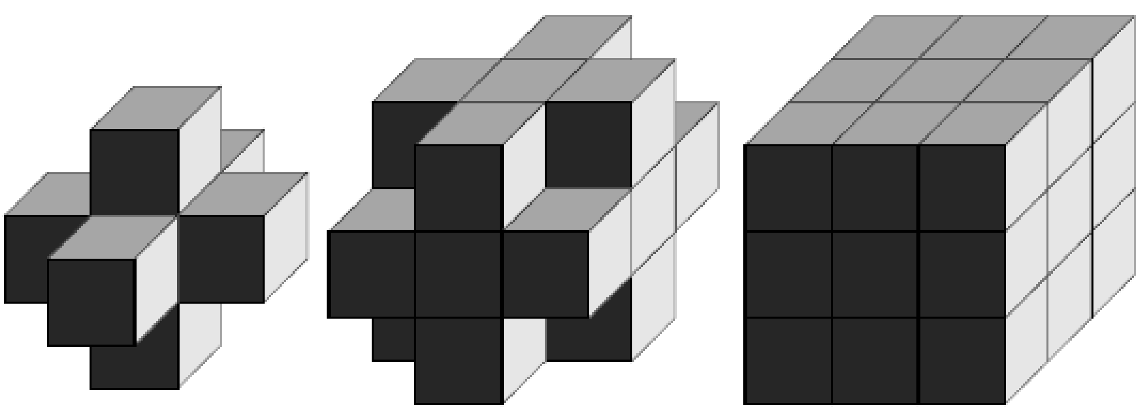
- Hexagon:
  - 6 neighbors
  - 2 configurations



Courtesy D. Coeurjolly & I. Sivignon

Adjacency on a voxel grid

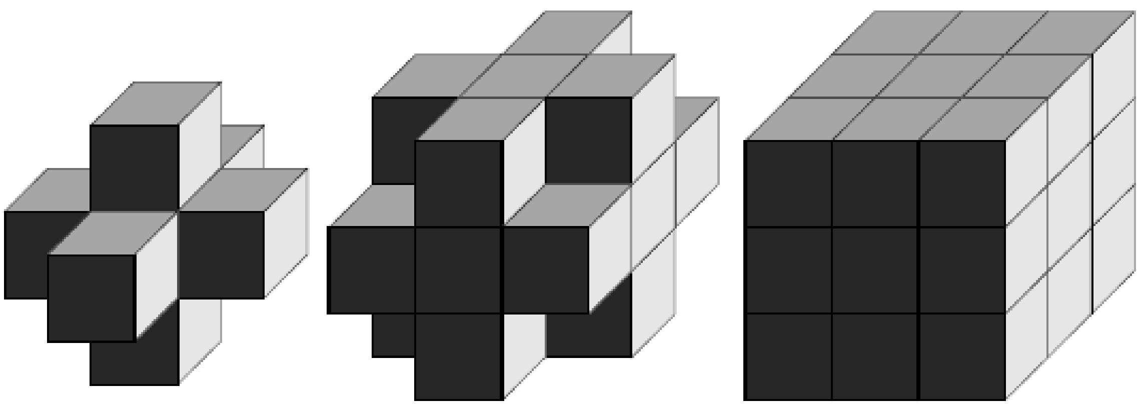
- (Combinatorial) Def.:
  - 6-neighbors = voxels that share a face
  - 18-neighbors = voxels that share a edge
  - 26-neighbors = voxels that share a vertex



Courtesy D. Coeurjolly & I. Sivignon

Adjacency on a voxel grid

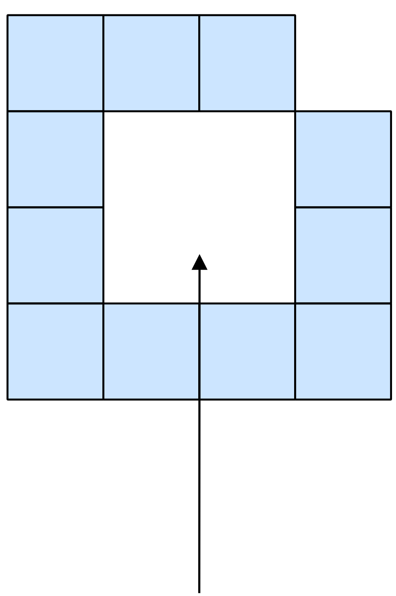
- (Topological) Def.:
  - 2-neighbors = voxels that share a face
  - 1-neighbors = voxels that share a edge
  - 0-neighbors = voxels that share a vertex



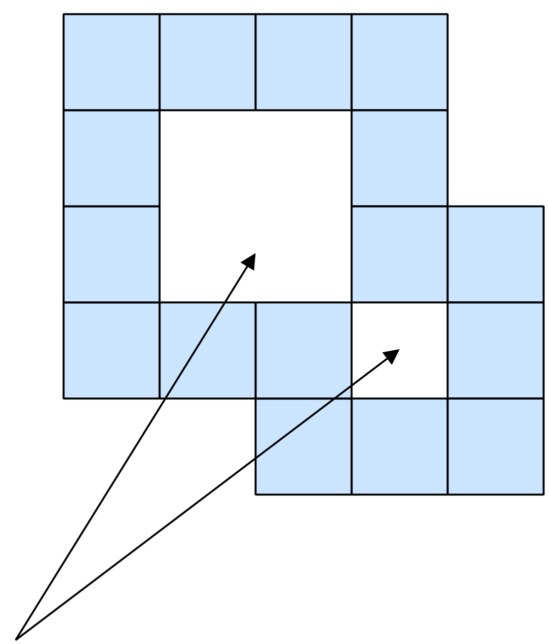
Courtesy D. Coeurjolly & I. Sivignon

Discrete object boundary

- Problem with discrete objects: their boundary is not obvious



Inside or outside ?



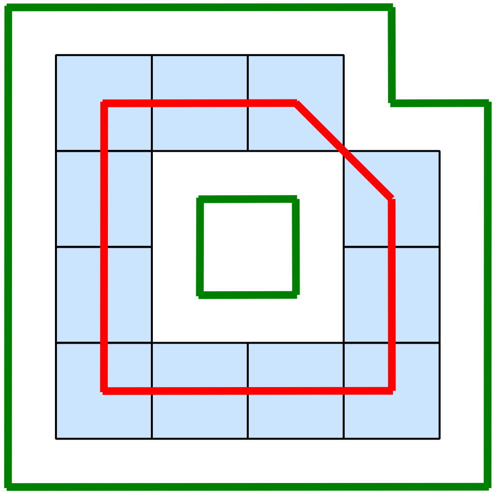
One or two components ?

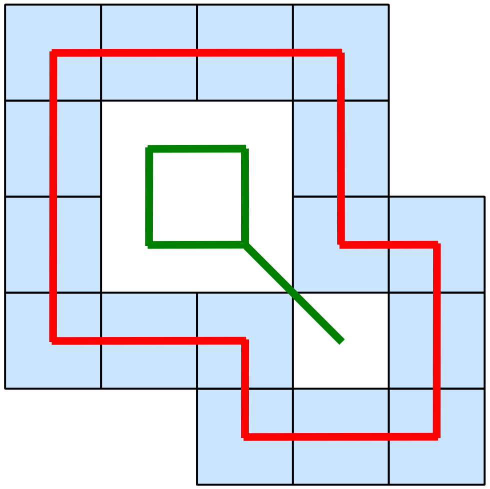
Problem

- Jordan's theorem: every smooth (n-1)-manifold in $\mathbb{R}^n$ disjoints space into two connected domains (the inside and the outside); it is the common boundary of these domains
- Corollary: impossible to find a path from inside to outside
- Need to define the right adjacency !

Adjacency couple

- Need to define one connexity for the (inside) object, and one for the outside

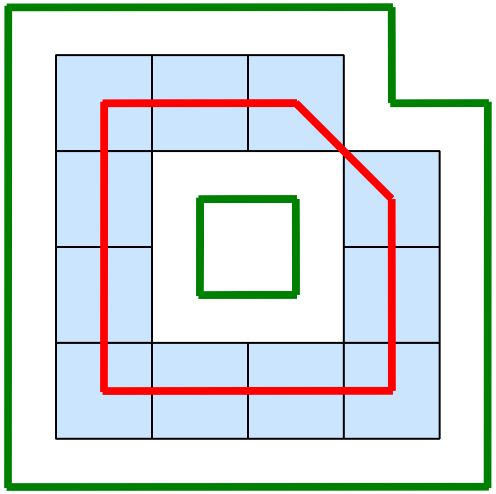


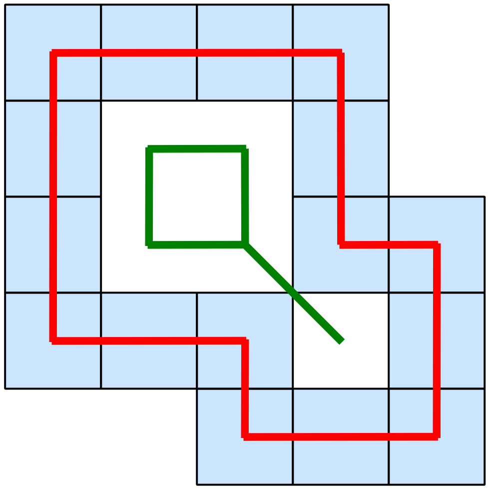


- Exercise: possible couples?

Adjacency couple

- Need to define one connexity for the (inside) object, and one for the outside

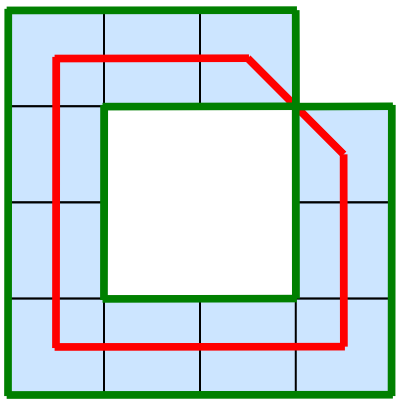


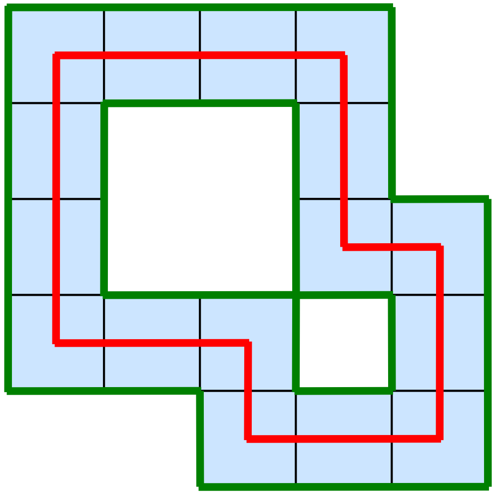


- Possible couples: (6, 18), (6, 26), (18, 6) and (26, 6)

Contour

- Def.: connected set of cell faces between a cell inside the object and a cell outside





- Coherent with Jordan; depends on the chosen adjacency
- Contour of a volume = surface (to display)

Discrete geometry

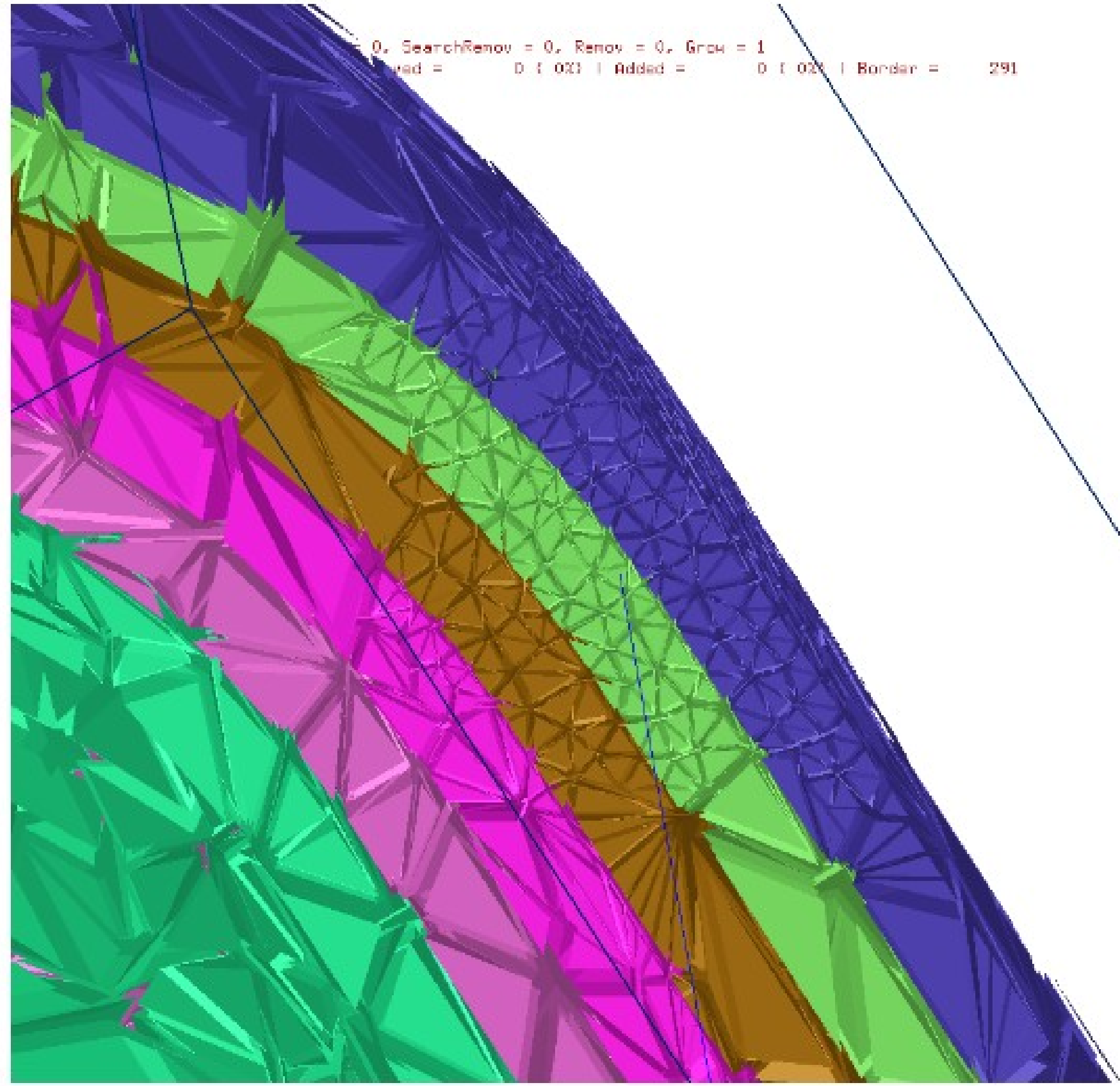
This part was inspired by a course given by
David Coeurjolly and Isabelle Sivignon
(CNRS researchers, LIRIS, Lyon)

Tetrahedra

Not talked about:

volume modeling with tetrahedra ("tets")

=> finite elements



Courtesy S.Barbier