Boundary representation, surfaces and meshes

GEO1004:
3D modelling of the built environment

https://3d.bk.tudelft.nl/courses/geo1004

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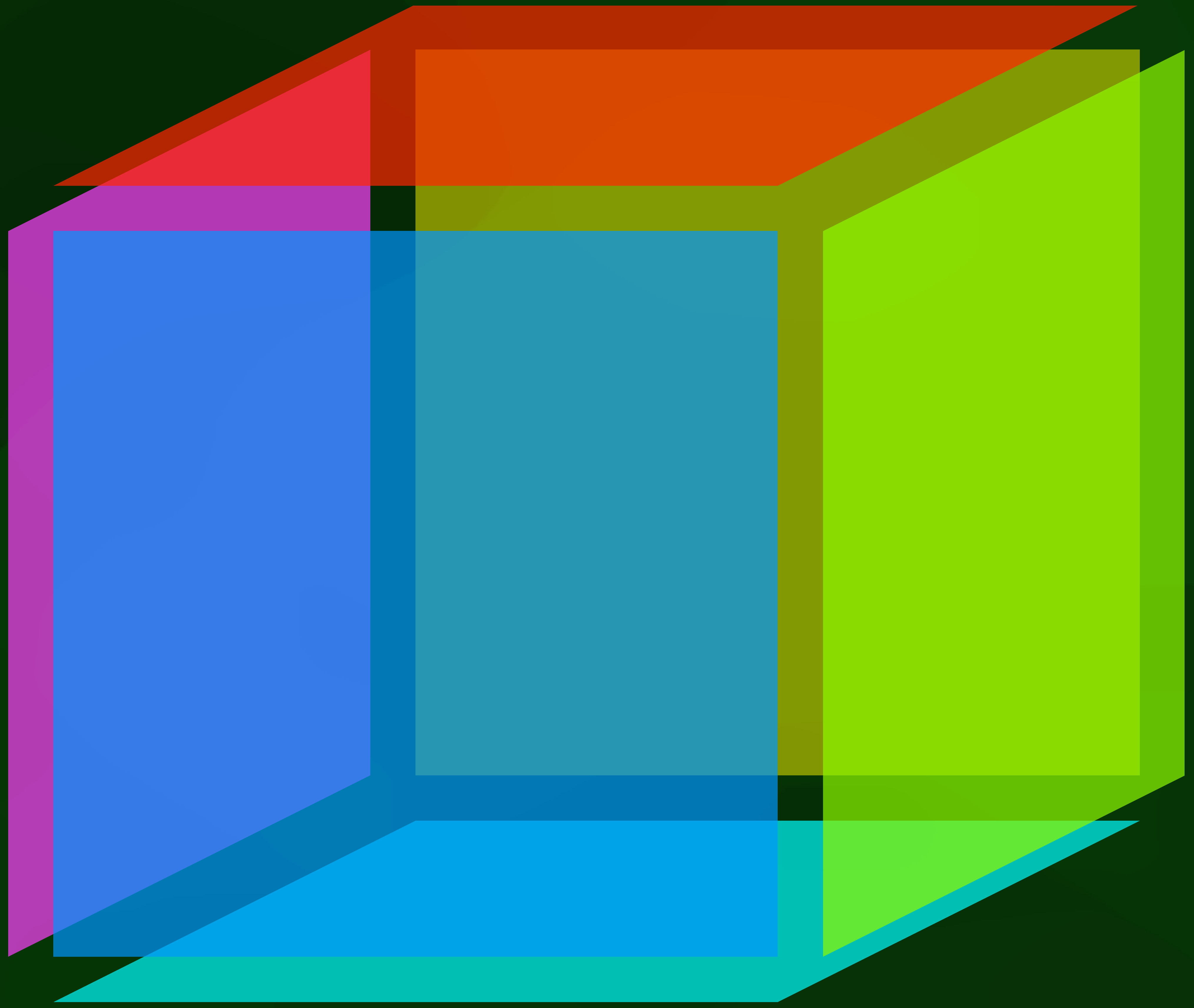
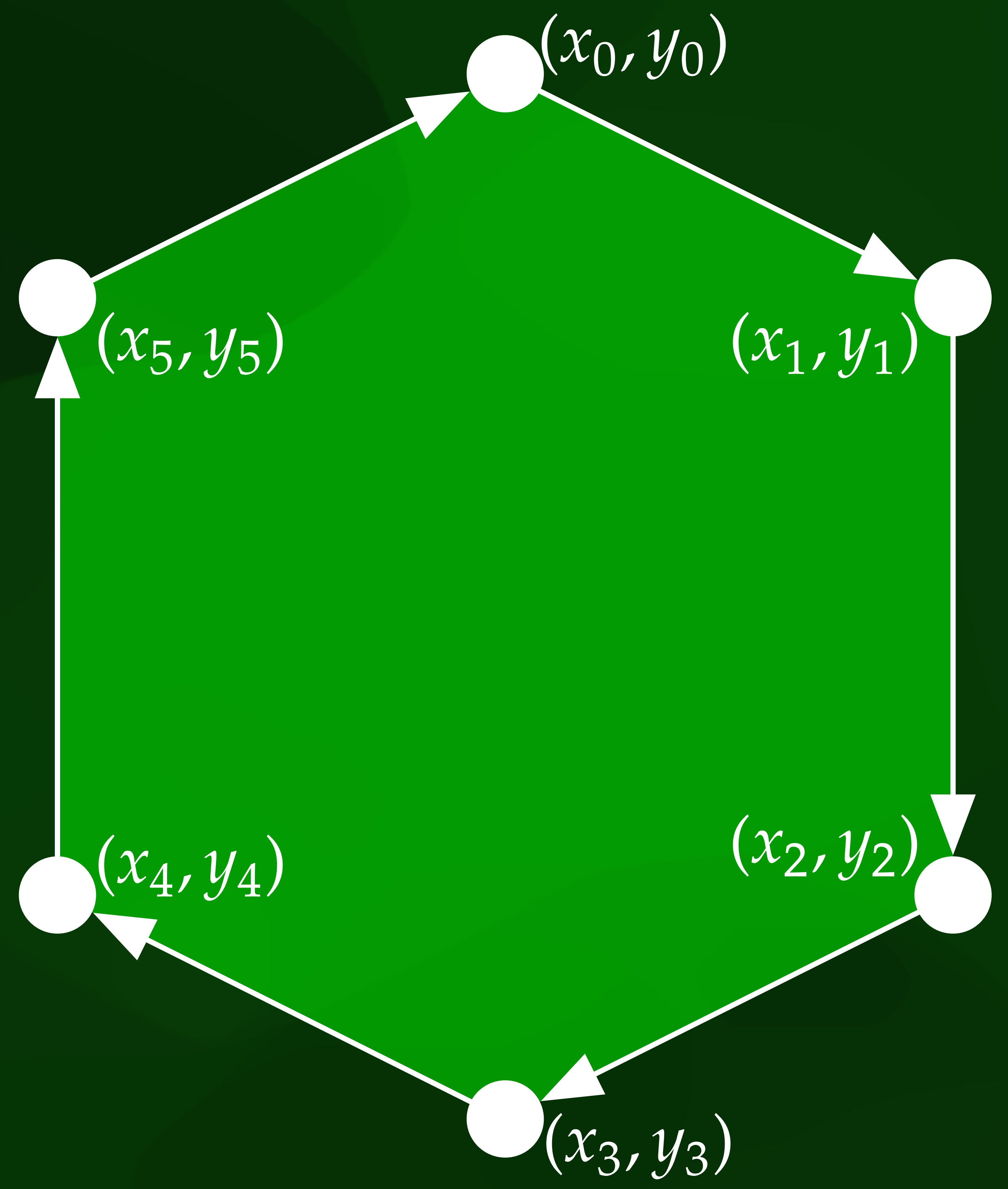
What is boundary representation?

- Also known as b-rep or surface modelling
- Representing an n-dimensional object through its $(n-1)$-dimensional boundary
- Most of the time: a 3D object through its 2D boundary

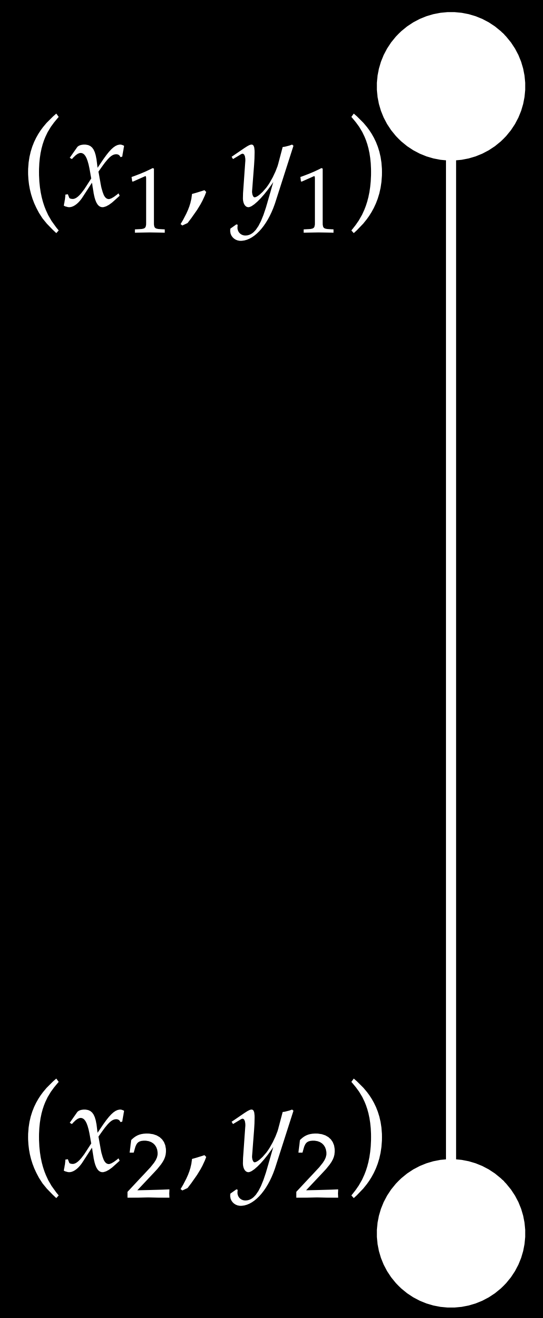


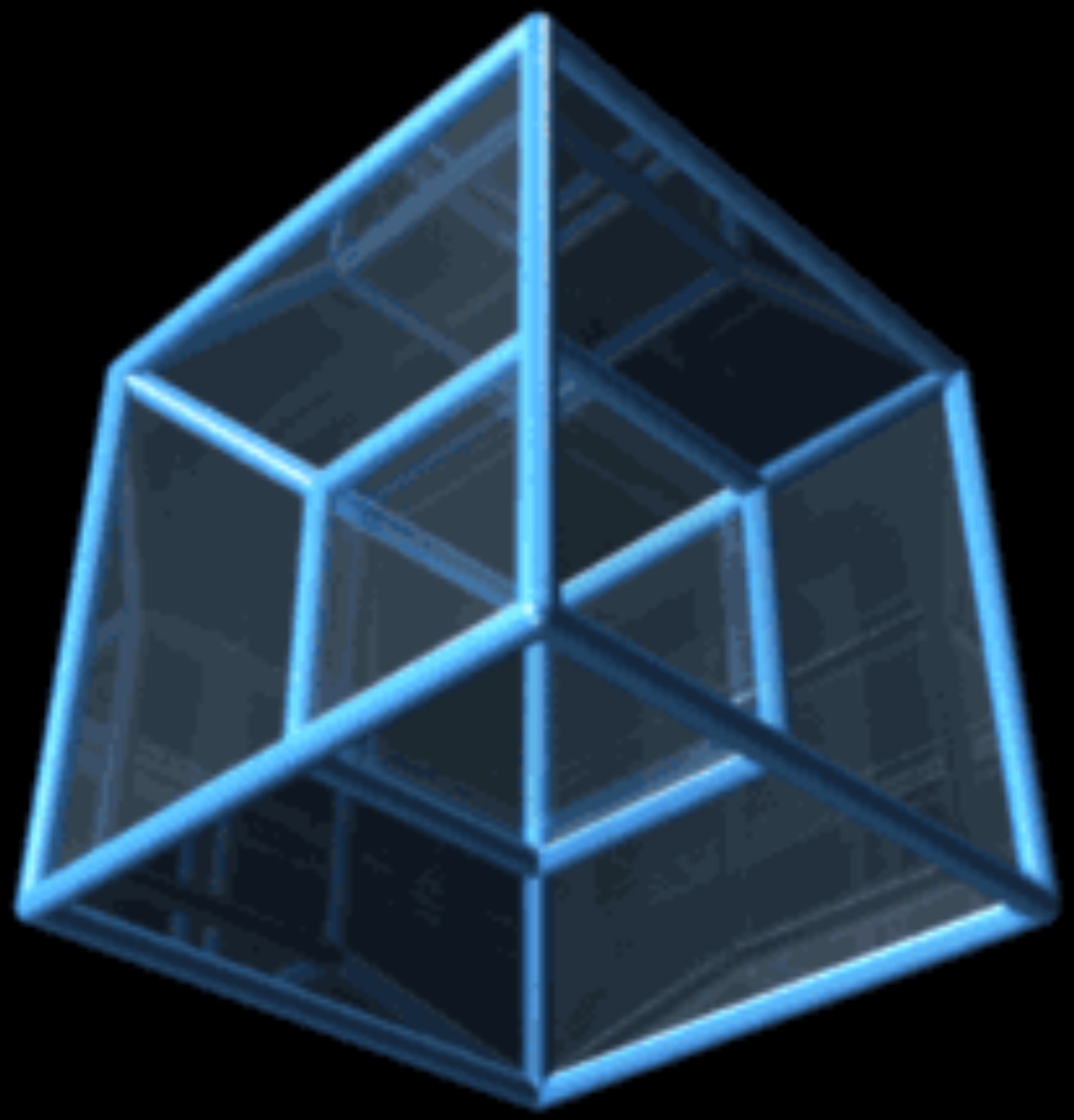
Why do it?

- Data structures for 2D are easier than data structures for 3D
  - Representing 2D polygons: as simple as a list of (x, y) vertices
  - Implicit assumption: there's a connection between each consecutive vertex and between the last and first



In any dimension





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Why does it work?

- In 2D, the Jordan curve theorem says: a closed curve separates the plane into two parts: an interior surface and an exterior surface

- In nD, the Jordan-Brouwer theorem, which in 3D says: a closed surface separates 3D space into two parts: an interior volume and an exterior volume.

b-rep in the 3D context

- store 3D objects by storing their 2D boundary
- … which can be split into a set of **surfaces** (in GIS usually triangles or polygons)
- … which can be represented using a (2D) **mesh**, i.e. a repetitive arrangement of simpler elements
- note: not the same as a 3D mesh (e.g. TEN)

Where?

- Every traditional GIS format (Shapefiles, GML, KML, GeoJSON, etc.)
- Most formats for 3D graphics (OBJ, PLY, VRML, COLLADA, glTF, etc.)
- Most implementations in DBs (PostGIS, Spatialite, MySQL, Oracle Spatial, etc.)
- Part of what is internally used in 3D modelling and 3D animation software, CAD and BIM, 3D games and game engines, etc.

Storing a 2D mesh

- Three basic approaches:
  - Split into triangles, then use a triangle-based structure
  - Keep as polygons, then use:
    - edge-based structures or
    - incidence graphs

Triangle-based structures

Some examples

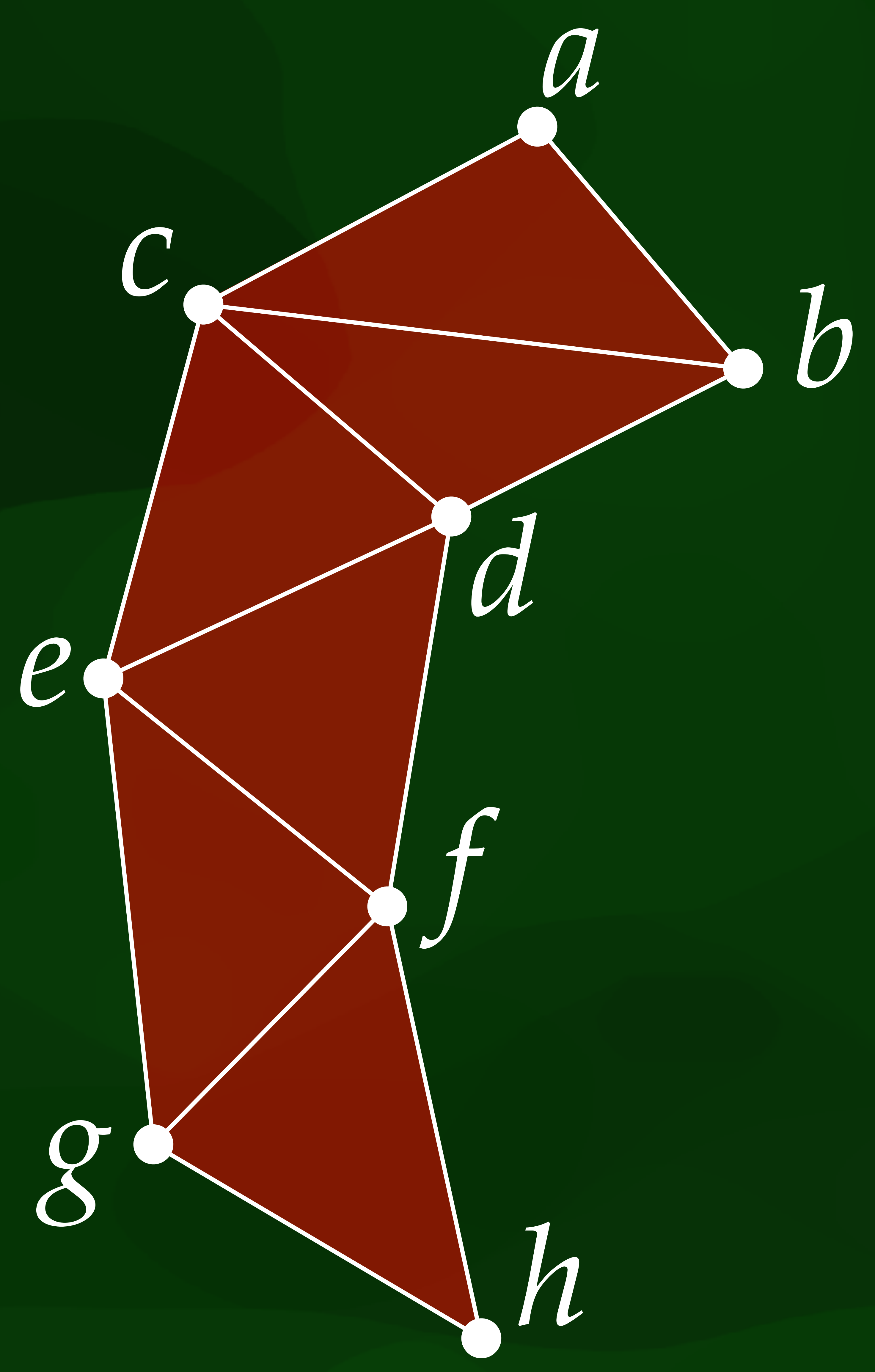
- Triangle DS as 3 points, i.e. coordinates of its 3 vertices (no topology)
- Triangle DS pointing to 3 vertex DS (vertex DS has coordinates)
- Triangle DS pointing to: 3 adjacent triangle DS and 3 vertex DS
- Triangle DS pointing to 3 adjacent triangle DS, 3 edge DS and 3 vertex DS

Example from CGAL

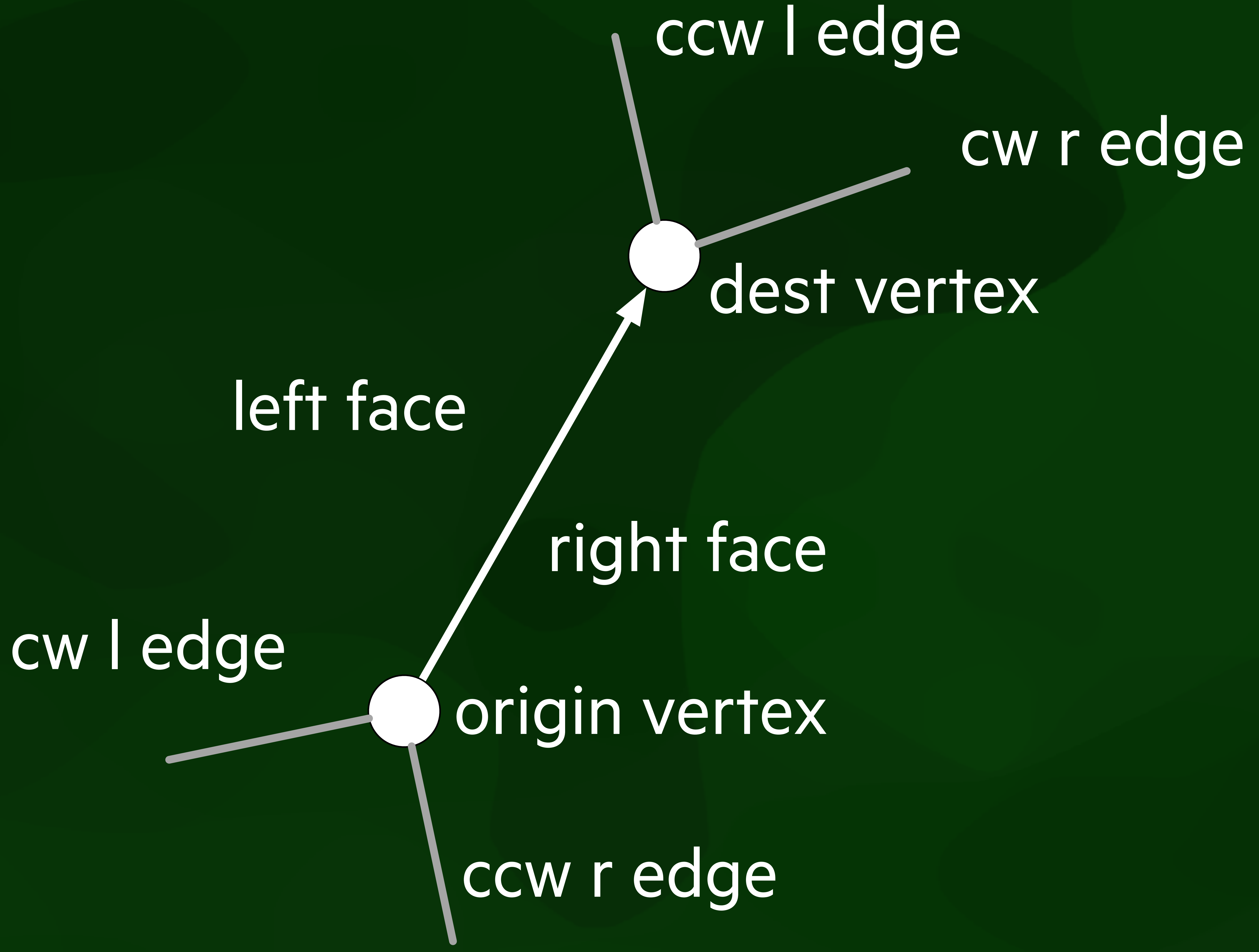
https://doc.cgal.org/latest/TDS_2/index.html

Compression of triangle DS

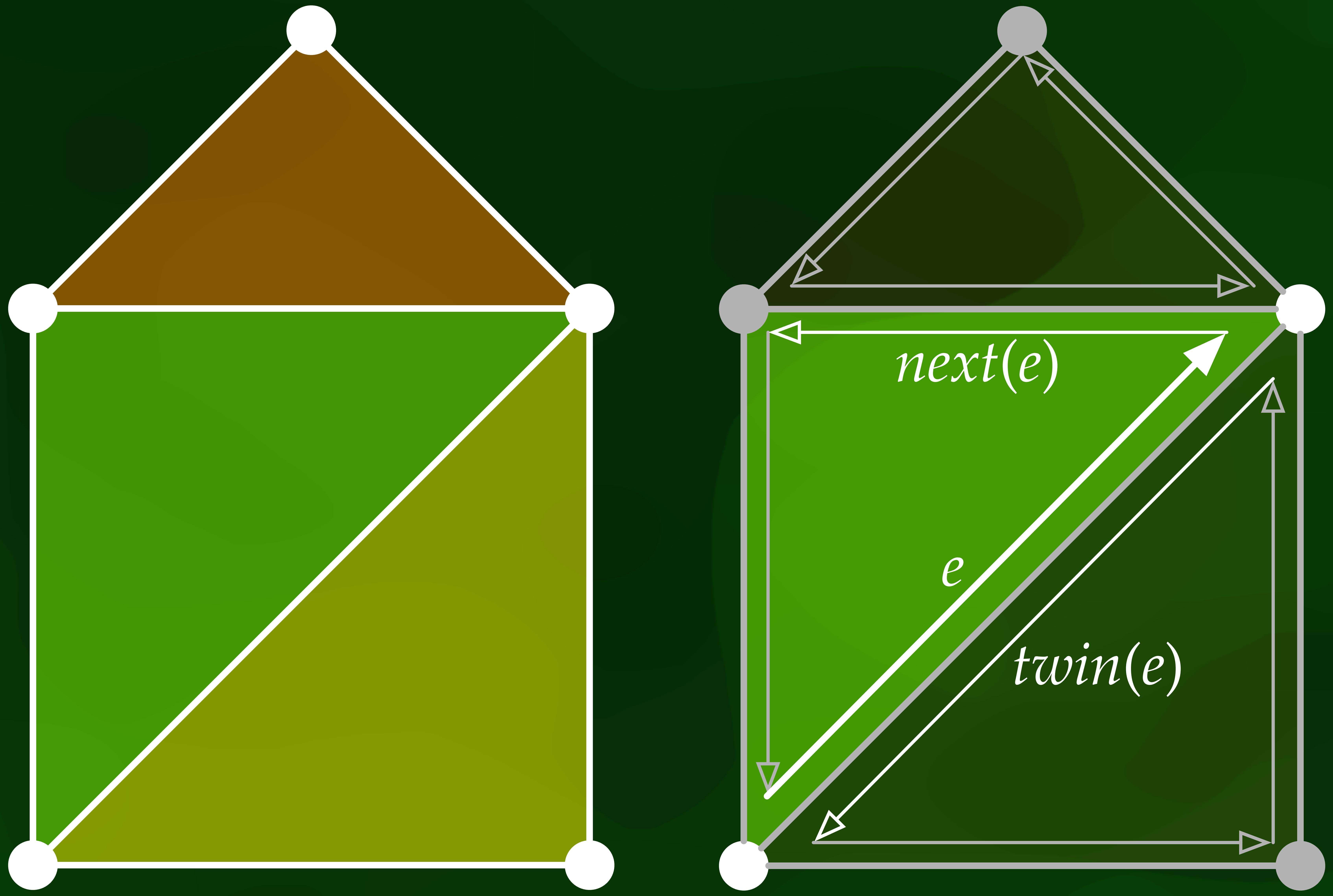
- Triangle strips
- Triangle fans
- Triangle stars
- …



Edge-based structures



Edge-based structures



Edge-based structures

- Essentially two types:
  - Full edges (e.g. winged edge, quad edge)
  - Half-edges (e.g. DCEL, 2D combinatorial maps)

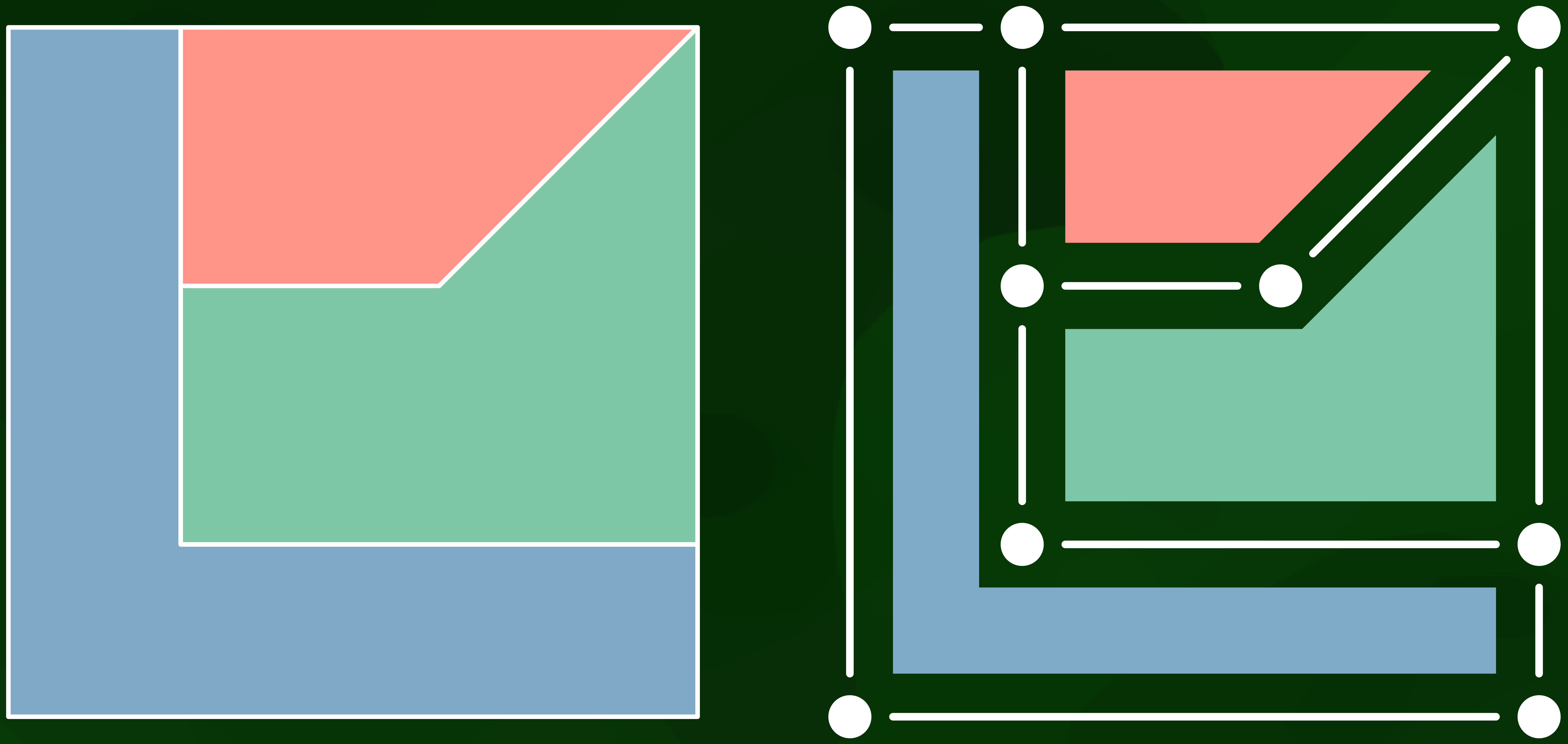
Example from CGAL

https://doc.cgal.org/latest/HalfedgeDS/index.html

Incidence graphs

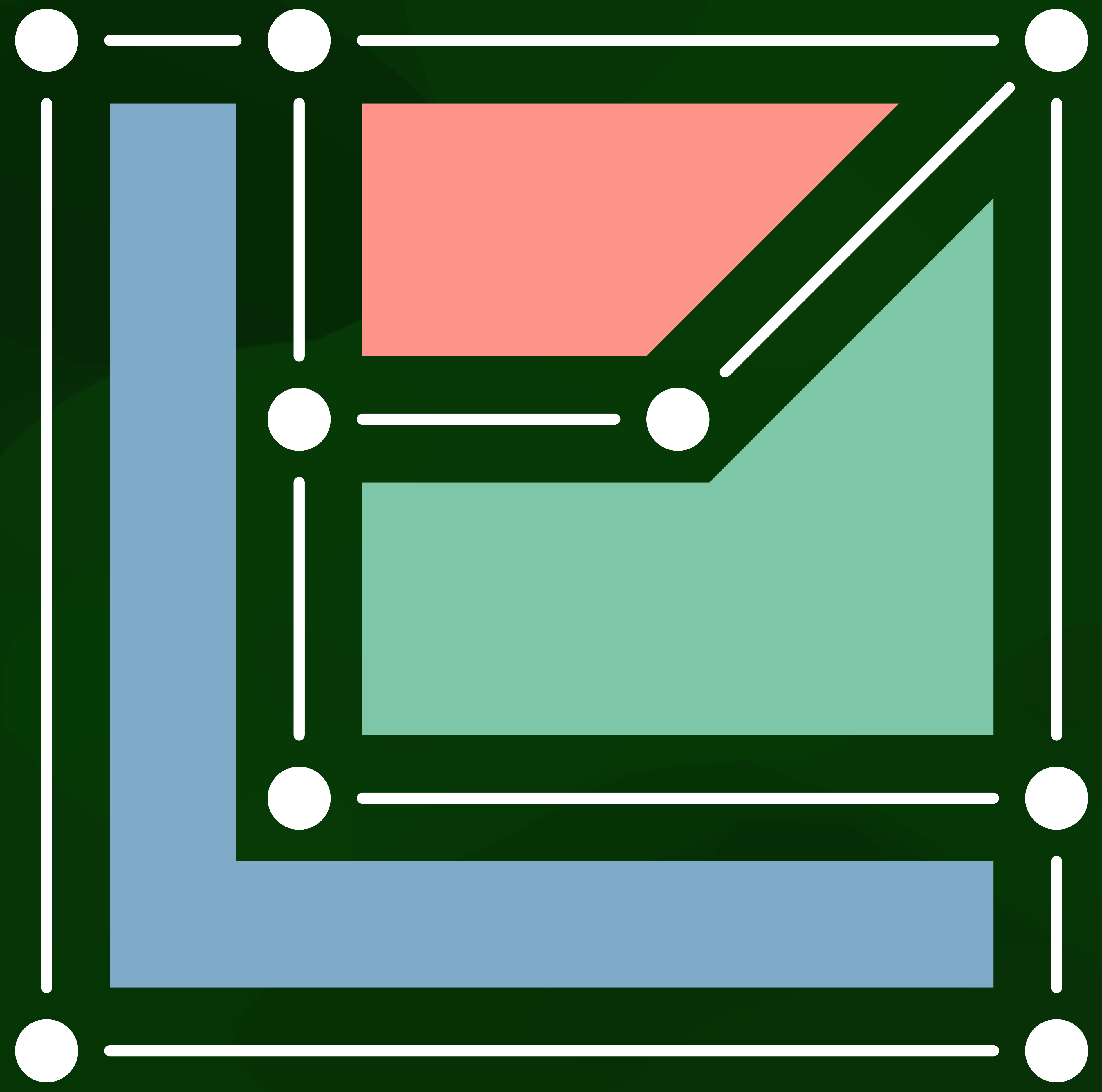
- Adjacency/incidence? neighbouring objects
  - Adjacency: same dimension
  - Incidence: different dimension

Incidence graphs

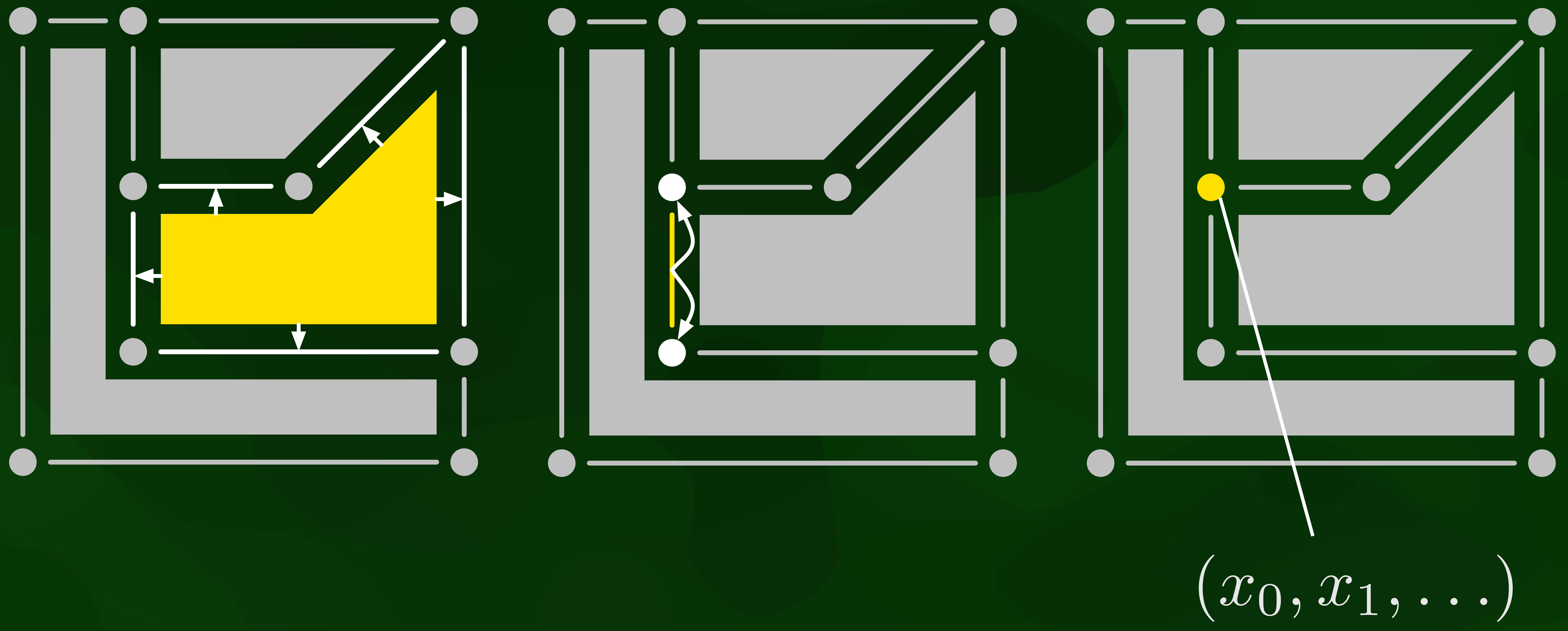


Incidence graphs

- Two edges are adjacent if they share an incident vertex
- Two faces are adjacent in they share an incident edge
- Less common but also:
  - Two vertices are adjacent if they share an incident edge
  - Two edges are adjacent if they share an incident face

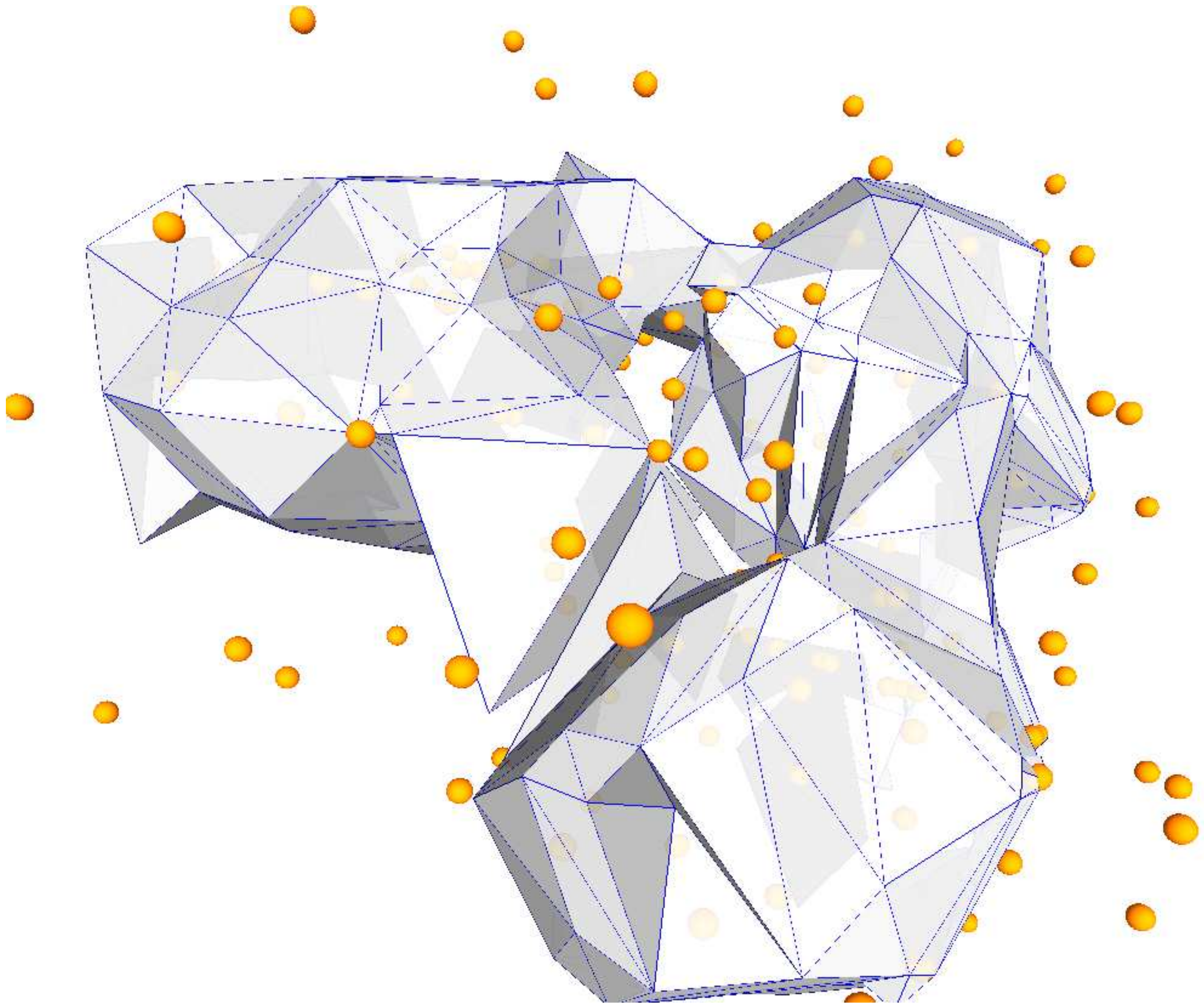


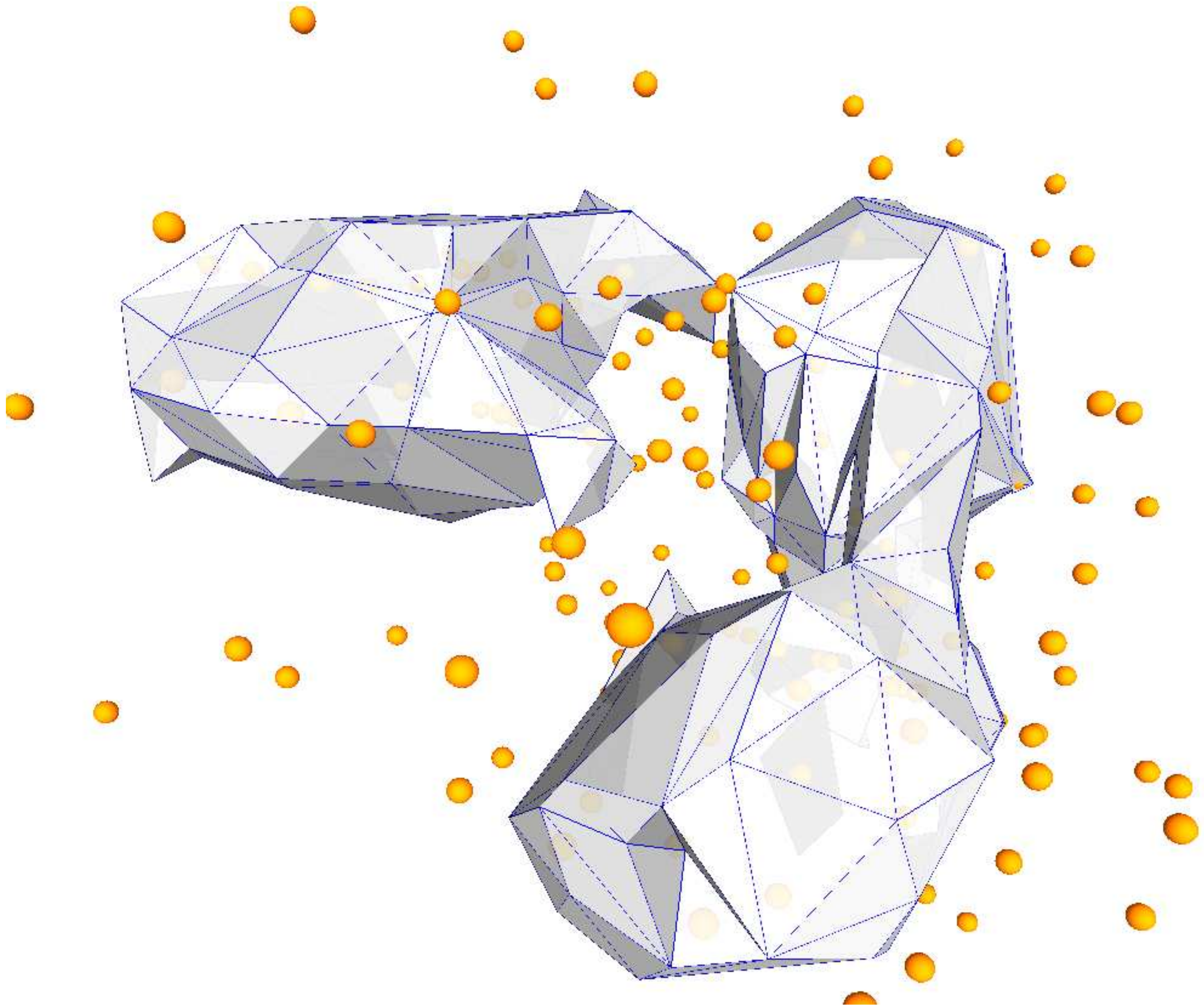
Incidence graphs



B-rep in fields: isosurfaces

- Not boundary of object -> boundary of level set





Homework 1 intro

What to do next?

1. Today:
    - Go to geo1004 website and study today’s lesson (3D book Chapter 2)
    - Get started with Homework 1
2. Wednesday: 3D Voronoi demos, then help with lessons or Hw 1

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