Visualisation, Rendering and Animation

2 VO / 1 KU (2001-2004)

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Short podcast version 2020

Rendering Polygonal Scene

- 1. Extract polygons from the database
- 2. Transform to WC and VRC
- 3. Backface culling and visibility
- 4. Clip against the visible volume
- 5. Projection of clipped polygons
- 6. Shading by incremental shader:
  - 1. Rasterize,
  - 2. Depth and visibility, (z-buffer)
  - 3. Shading (constant, Gouraud, Phong…)

2. Data Structures & Data Formats

Ways of object representation

Object Representations

- Curves and Surfaces
- Solid Modeling
  - Boundary Representation
  - Spatial Enumeration Models
    - Spatial-Occupancy Enumeration (Voxel)
    - Binary Space Partitioning (BSP) Trees
    - Octrees
  - Constructive Solid Geometry (CSG)
  - Function Representation (F-rep)

Criteria

Modeling:

- Representation Power
- Transformation / Combination
- Interactivity Support
- Multiple Use, Generality

Rendering:

- Representation Precision
- Memory Requirements

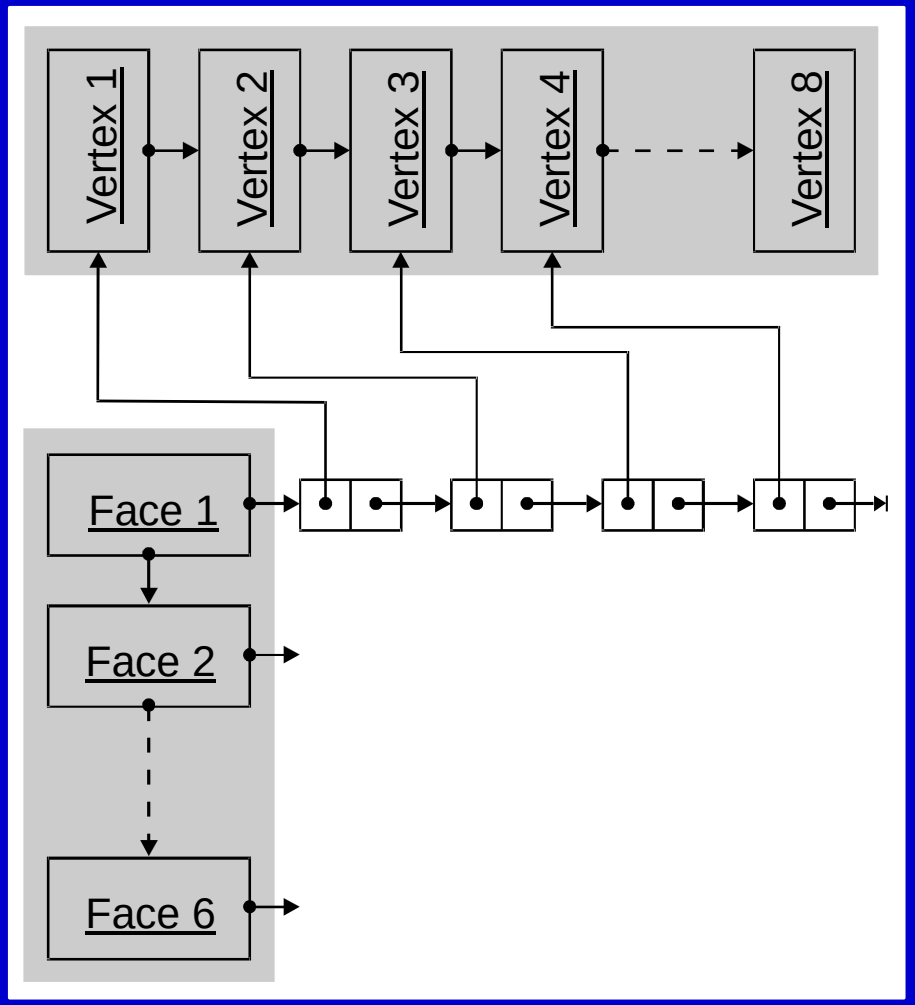
Boundary Representation, B-rep

Point List

- Element: 3D-coordinates
- Linked Lists

Face Lists

- Element: Index List to the 3D-points
- Linked Lists



B-rep Advantages/Disadvantages

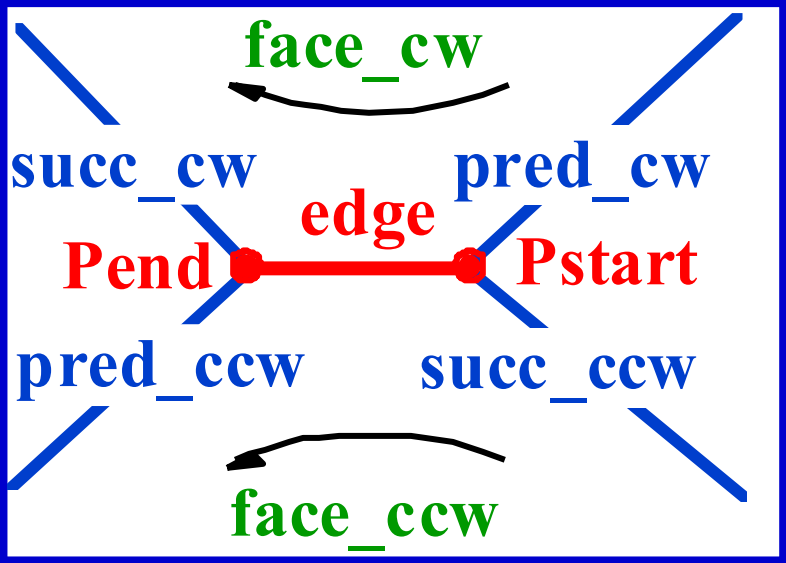
- **Pros**
  - Simple transformations
  - General representation
  - Supported by many graphics libraries
- **Cons, drawbacks**
  - Higher memory requirements
  - Combinations necessary and non-robust
  - Curved objects – approximation

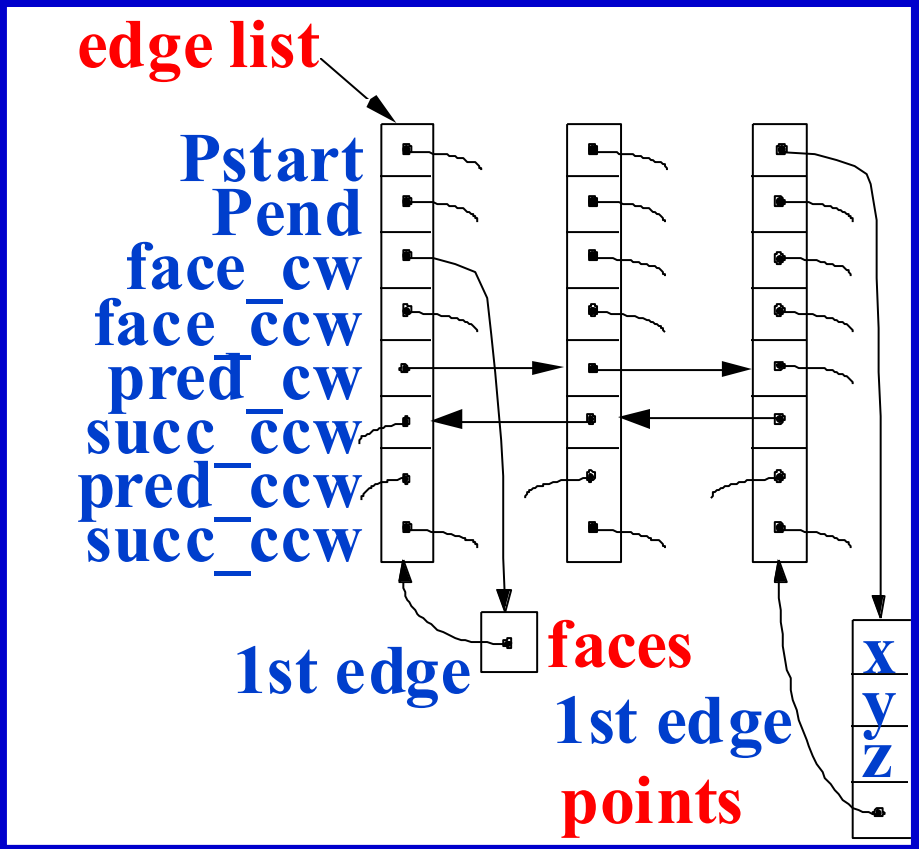
IndexedFaceSet (VRML97)

```
Shape {
  geometry IndexedFaceSet {
    coord Coordinate {
      point [
        x0 y0 z0,     # vertex 0
      ]
    }
    coordIndex [
      0, 1, 4, 2, -1, # face 0
    ]
  }
}
```

Winged Edge Data Structure

- Alternative to hierarchic B-Rep.
- Central element is the edge:



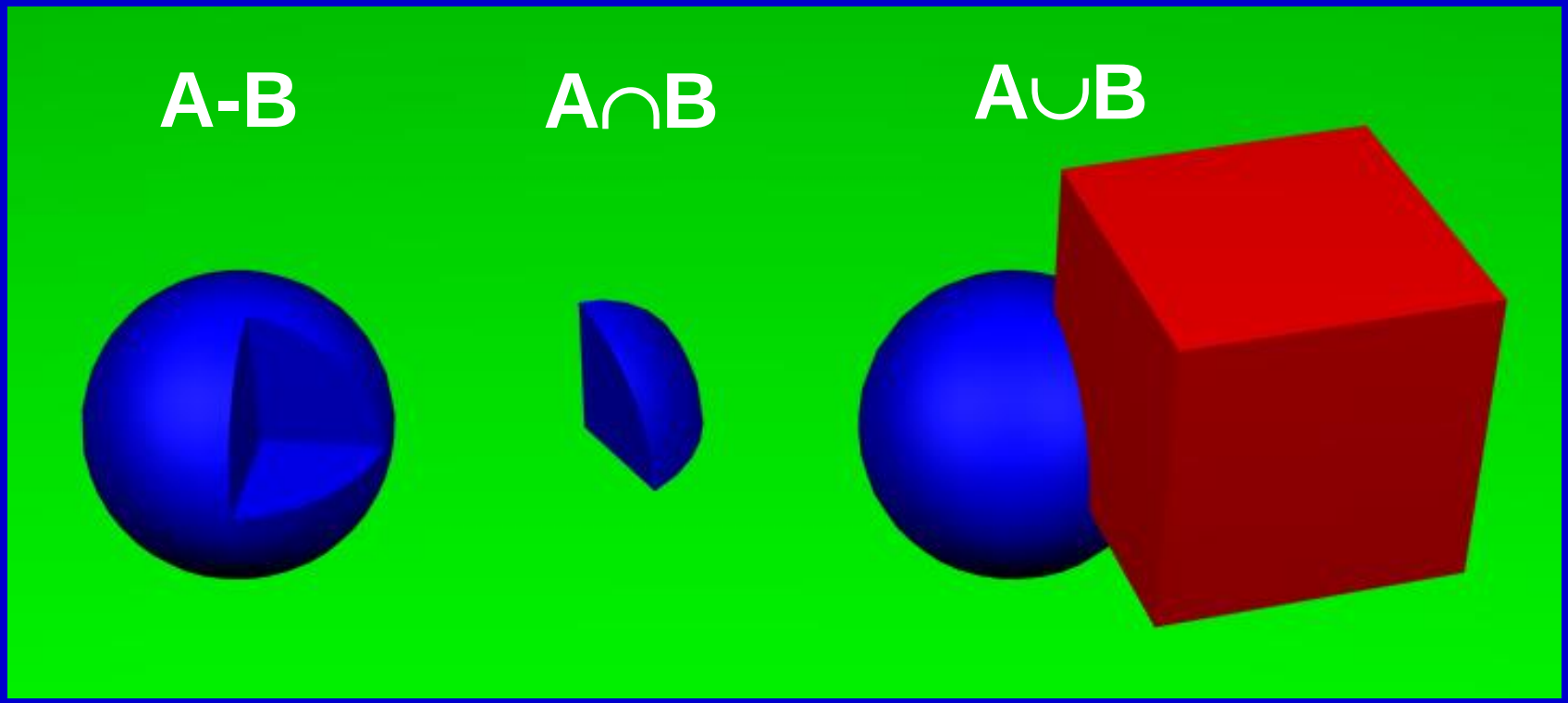


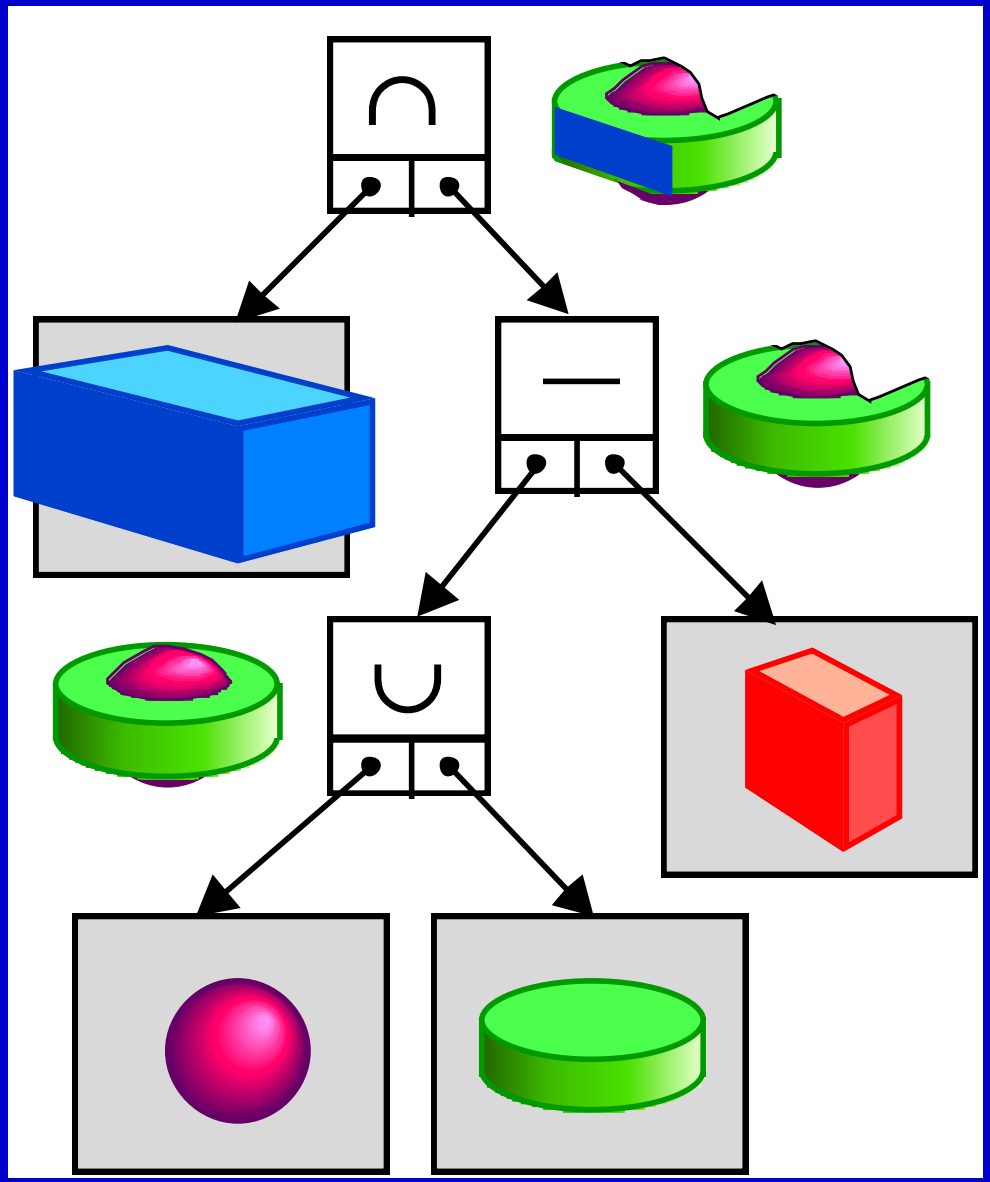
Constructive Solid Geometry

- Composition of primitives
- Primitives: sphere, cone, cube, cylinder, ...
- Operations: +, -, ∩, ∪, ...
- Primitives in the leafs and operations build the rest nodes of the CSG-tree

Boolean Operations

Using 3 operators enables for all possible combinations - not uniquely





Easy Modeling Methods

Task:

Create the Object Description for later Processing within the Rendering- and Output-Modul.

Generated via:

- *User Interaction*
- *Automatically (eg „Object-Scanner“, range images, ...)*

- **Elementary Objects**
  - Primitives, regular polyhedra, ...
  - Sweeps
  - Free-form patches
  - (Super-)Quadrics
  - Terrain (DTM, DEM)
  - Fractal Mountains
  - Soft Objects
  - Particle Systems
  - Natural Phenomena…
- **Transformations**
  - linear ones
  - twist, blending ... (Verbiegeoperationen)
  - local operations
- **Combining methods**
  - Boolean Operations with Elementary Objects (CSG)
  - F-rep
  - (Solid Modeler UI)

Sweeps

Idea:

Move a 2D-Object (Contour) in the space. All enclosed points generate the object swept.

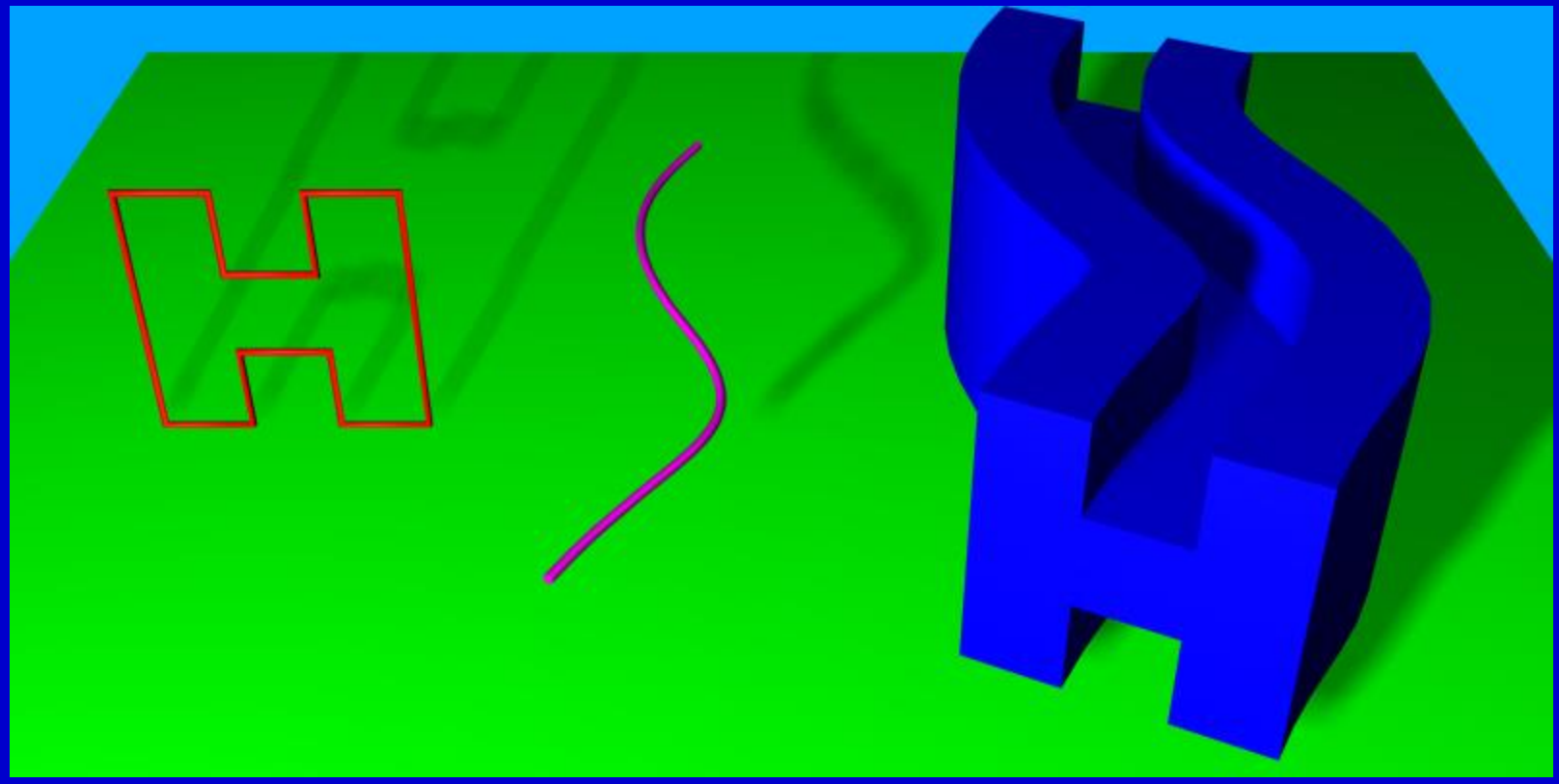
Forms:

- translational sweep
- rotational sweep
- conical sweep
- sphere sweep
- general cylinder, …
- NOTE: Parametrisation

Translational Sweep

Method:

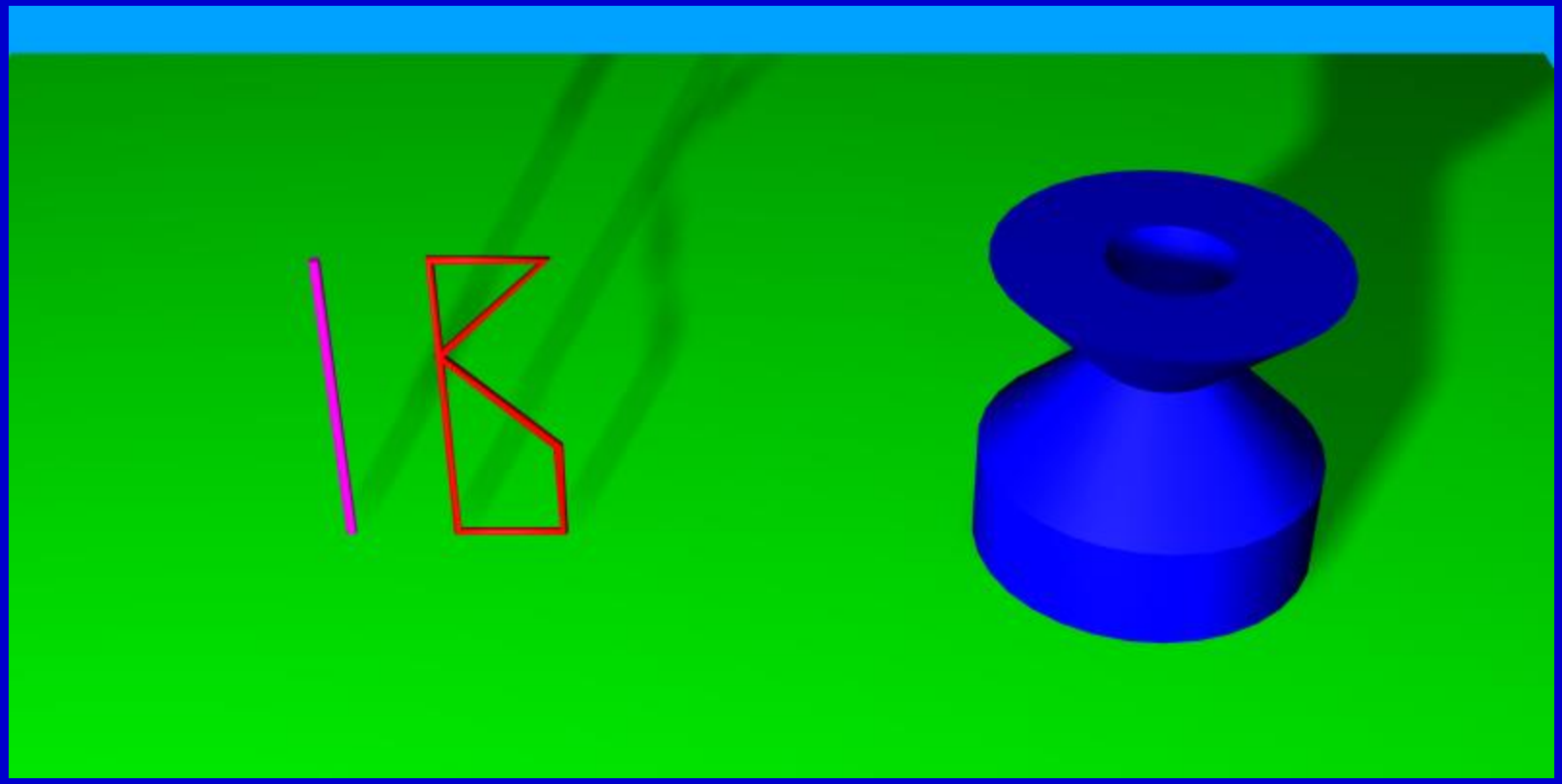
Define the object with the contour (2D) and the path.



Rotational Sweep

Method:

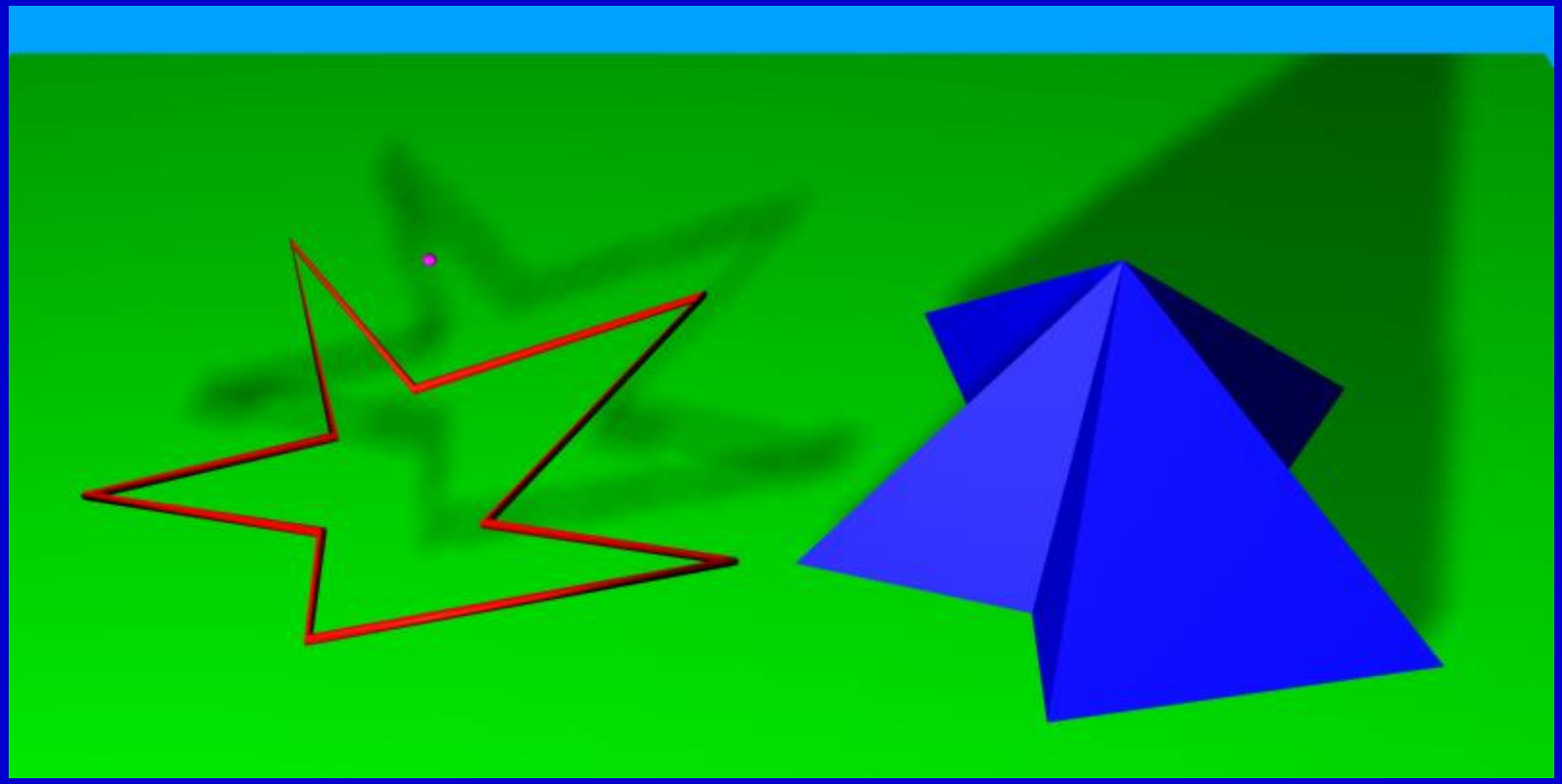
Define the object by rotating of the contour (2D) with the arbitrary axis.



Conical Sweep

Method:

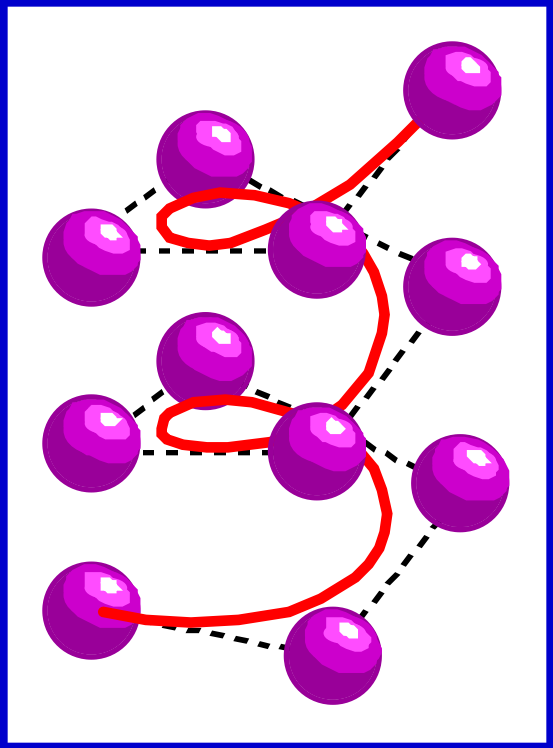
Define the object by the contour (2D) and a 3D-point (top of the pyramide).

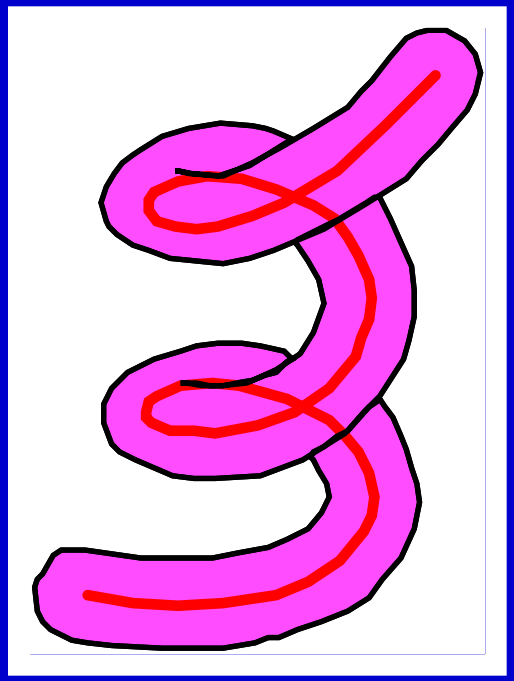


Sphere Sweep

Method:

Define the object by the sphere with the varying radius and a path.

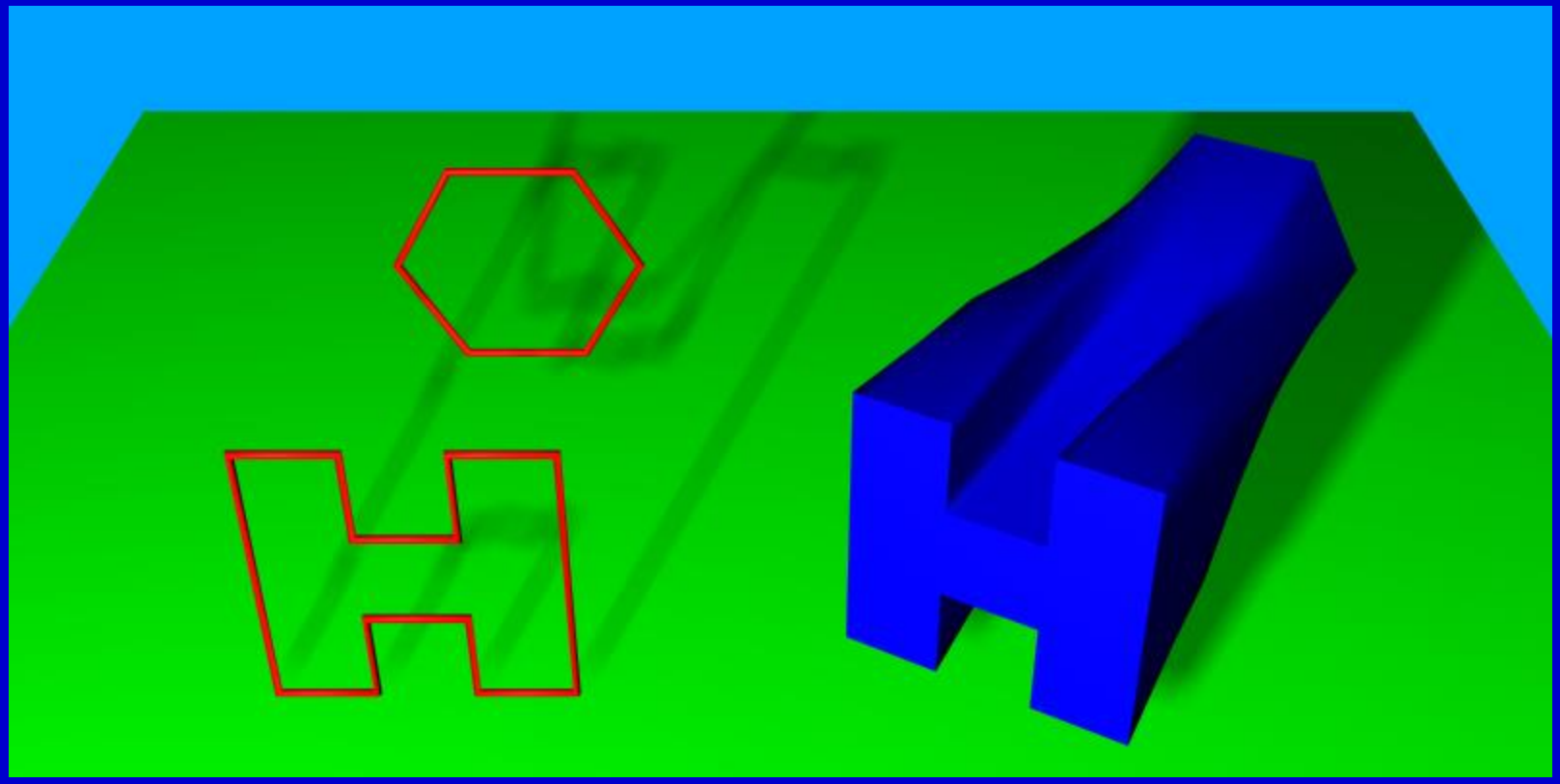




General Cylinder

Method:

Define the object by the set of „control“-contours and by the path.



Quadrics

Idea:

Quadrics are all objects, which is possible to describe using quadratic functions (polynomials).

Definition:

– *explicitly :*

$$x^2 + y^2 + z^2 = r^2$$

– *parametric:*

$$x = r \cos\alpha \cos\beta$$

$$y = r \cos\alpha \sin\beta$$

$$z = r \sin\alpha$$

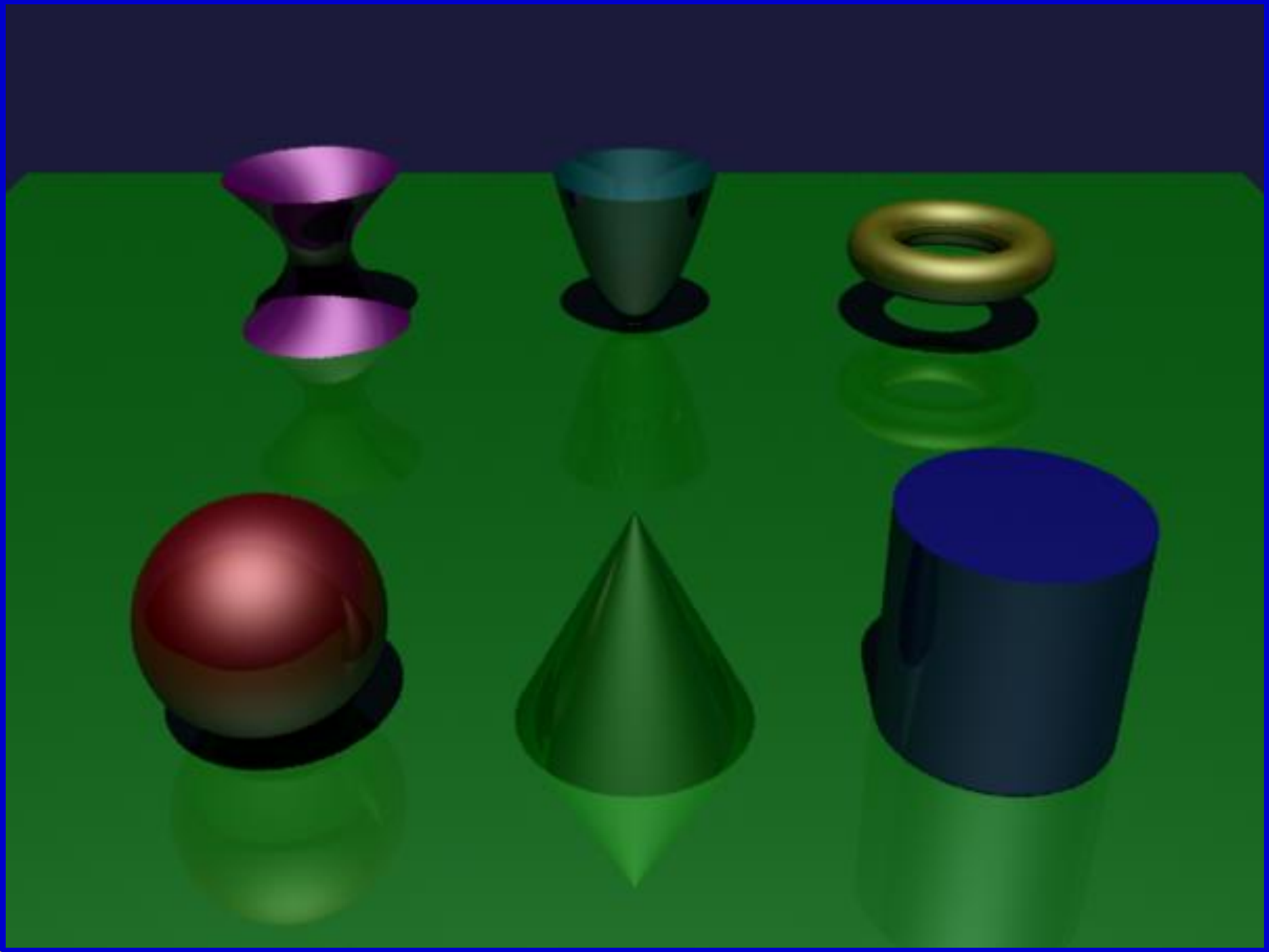
Quadrics (examples)

- Sphere: $x^2 + y^2 + z^2 = r^2$
- Cylinder: $x^2 + y^2 = r^2 \quad 0 \le z \le height$

  $x^2 + y^2 \le r^2 \quad z = 0 \text{ and } z = height$
- Conic: $x^2 + y^2 = z^2 \quad 0 \le z \le height$

  $x^2 + y^2 \le z^2 \quad z = height$
- Torus: $\left(x^2 + y^2 + z^2 + R^2 - r^2\right)$

  $-4\left(x^2 + y^2\right) = 0$



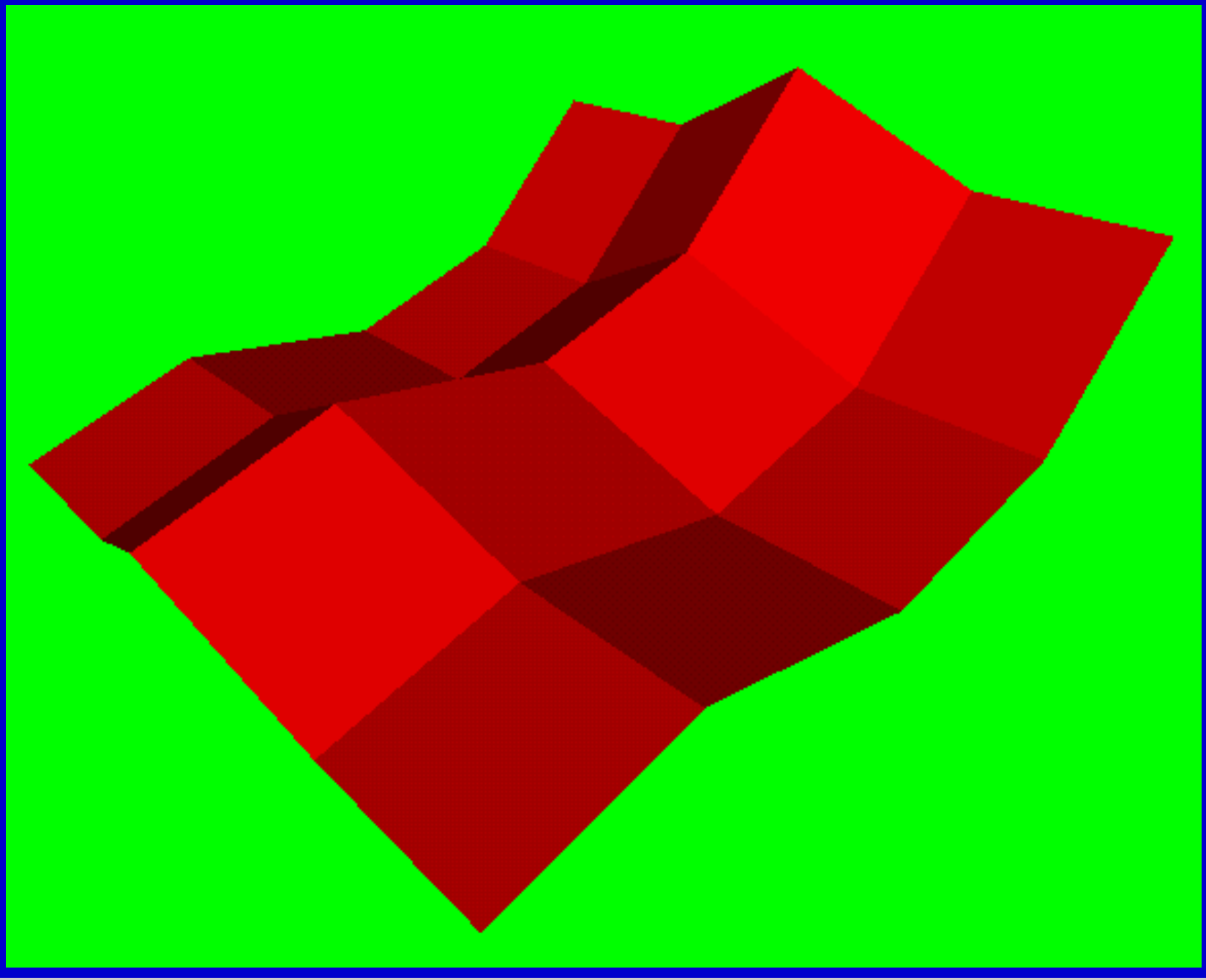
Terrain

Definition:

- Given the equidistant grid in the plane and in gridpoints the heigths (Z-coordinates). DEM (digital elevation model, field of heights).

Extension:

- More properties given for the terrain surface (eg Color), the DEM enriched by texturing DTM (digital terrain model).



Note on 2.5D Objects

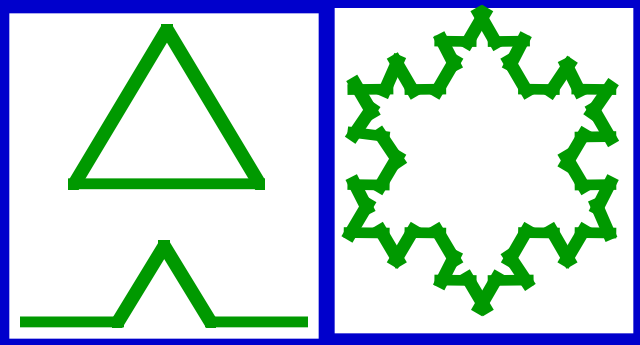
Definition:

– If the surface of terrain or sweeped solid can be adressed by 2 parameters, we speak about 2.5D objects.

Question:

– Which solids are 2.5D ones?

Fractal Mountains



Fractal - Koch‘s Curve:

- Initiator: Start with the polygon.
- Generator: Replace each line segment.

Fractal Mountains:

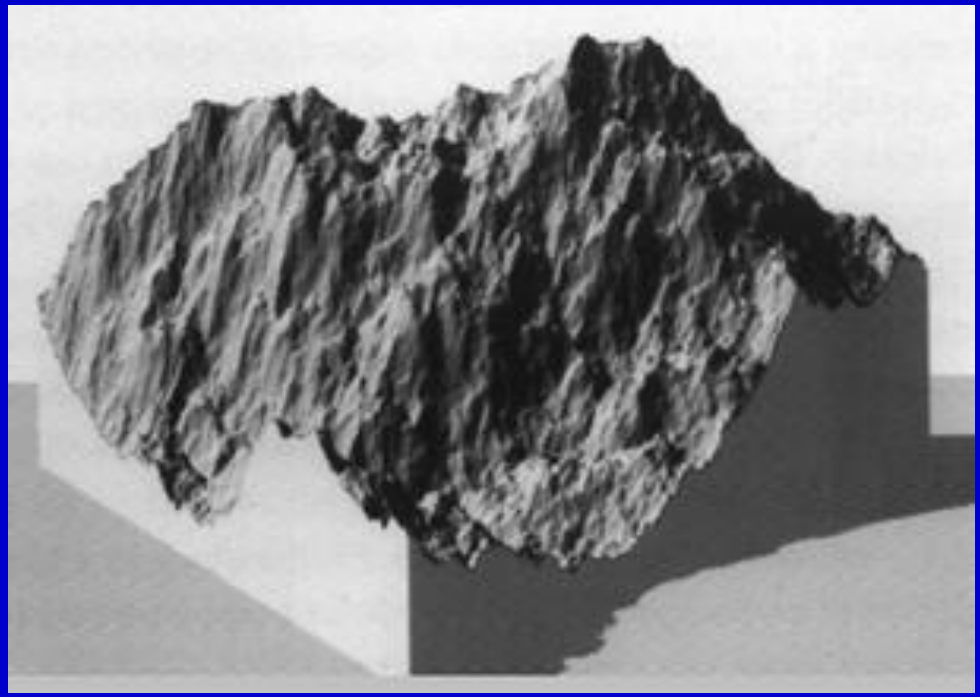
- Generator no more regular, but random one within the given borders Grenzen.
- Initiator: 1 triangle (or 2)
- Generator: each egde divide by a randomly generated point.

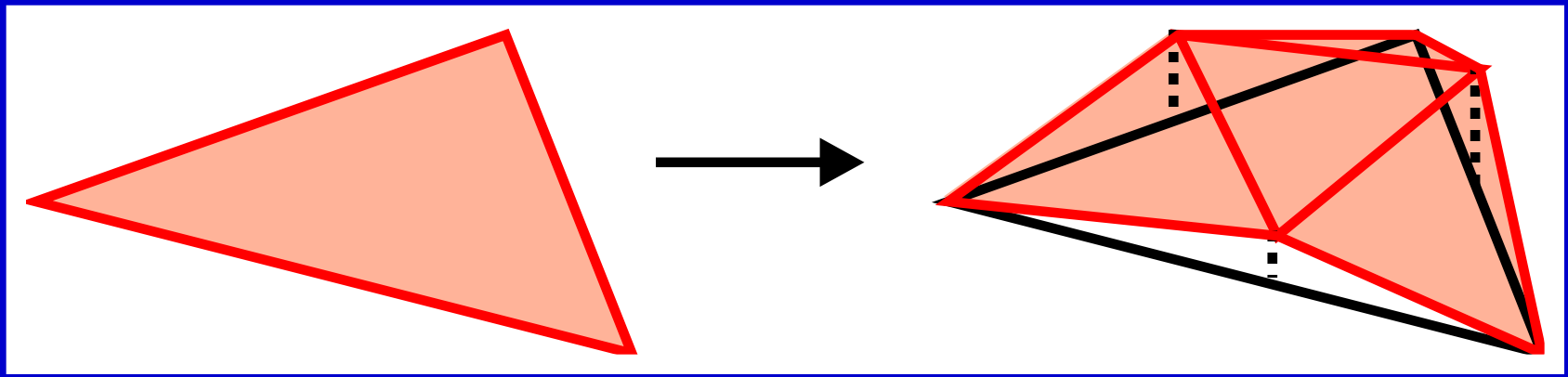
Fractal Mountains (algorithm)

Each Step:

from 1 triangle generate 4 new ones.

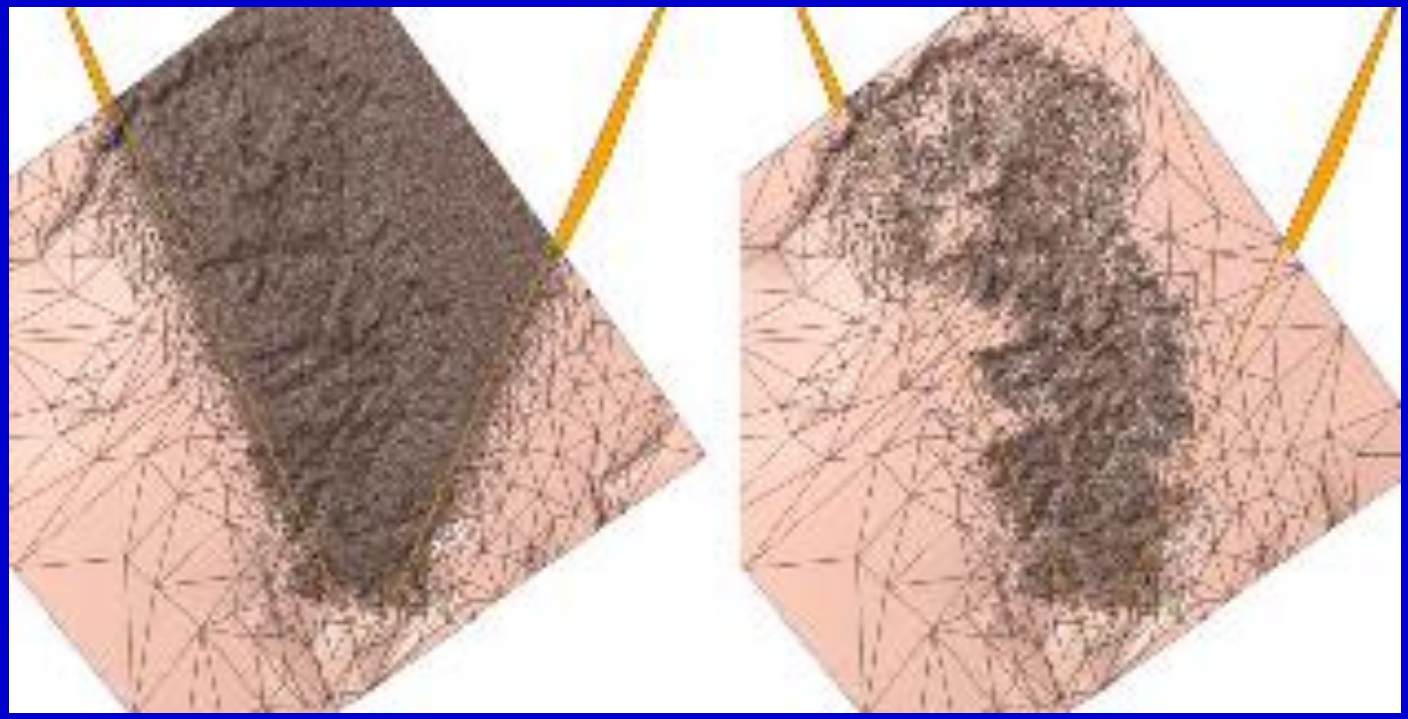
Subdivide until the Quality suffices.





Multiresolution, Area Subdivision

Oscar Winning Animations



Thank You...

… for Your attention.

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