

Visualisation, Rendering and Animation

2 VO / 1 KU (2001-2004)

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Short video 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*

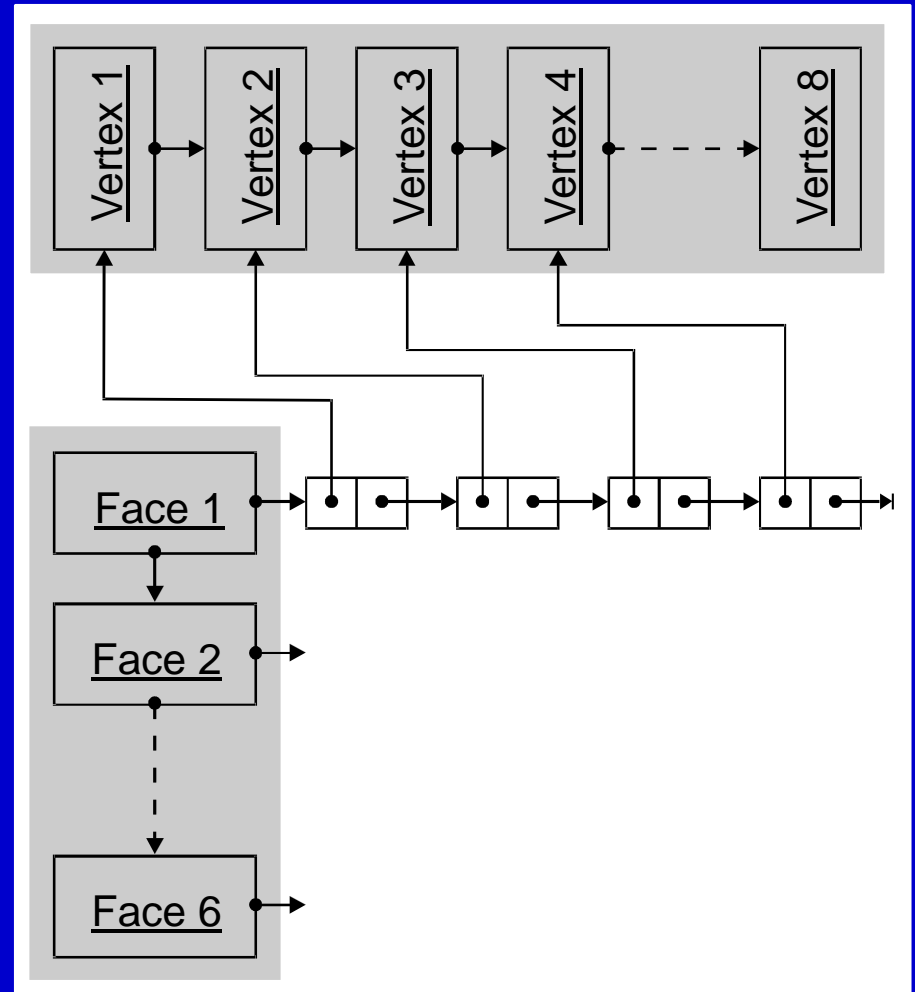
Boundary Representation, B-rep

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

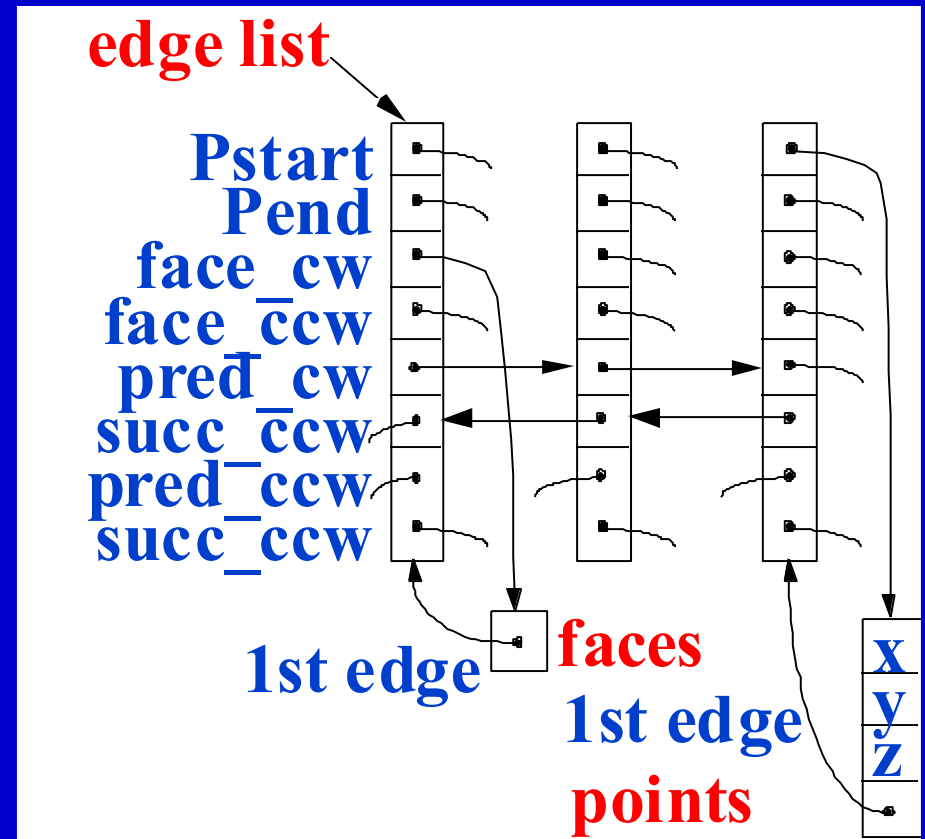
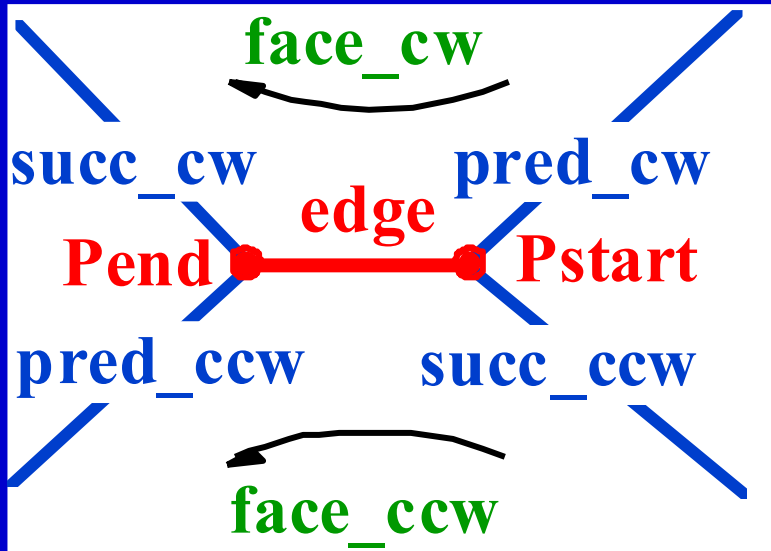
- *Higher memory requirements*
- *Combinations necessary and non-robust*
- *Curved objects – approximation*

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:

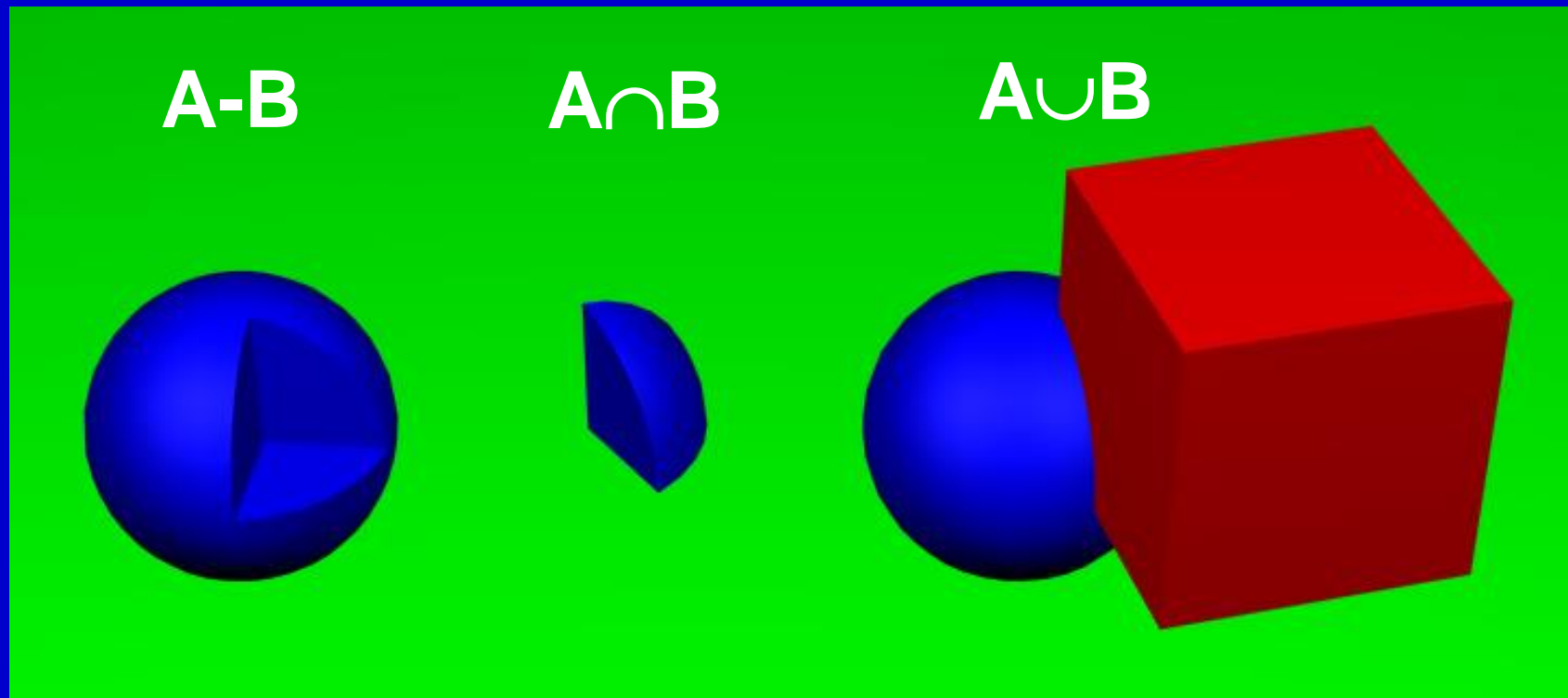


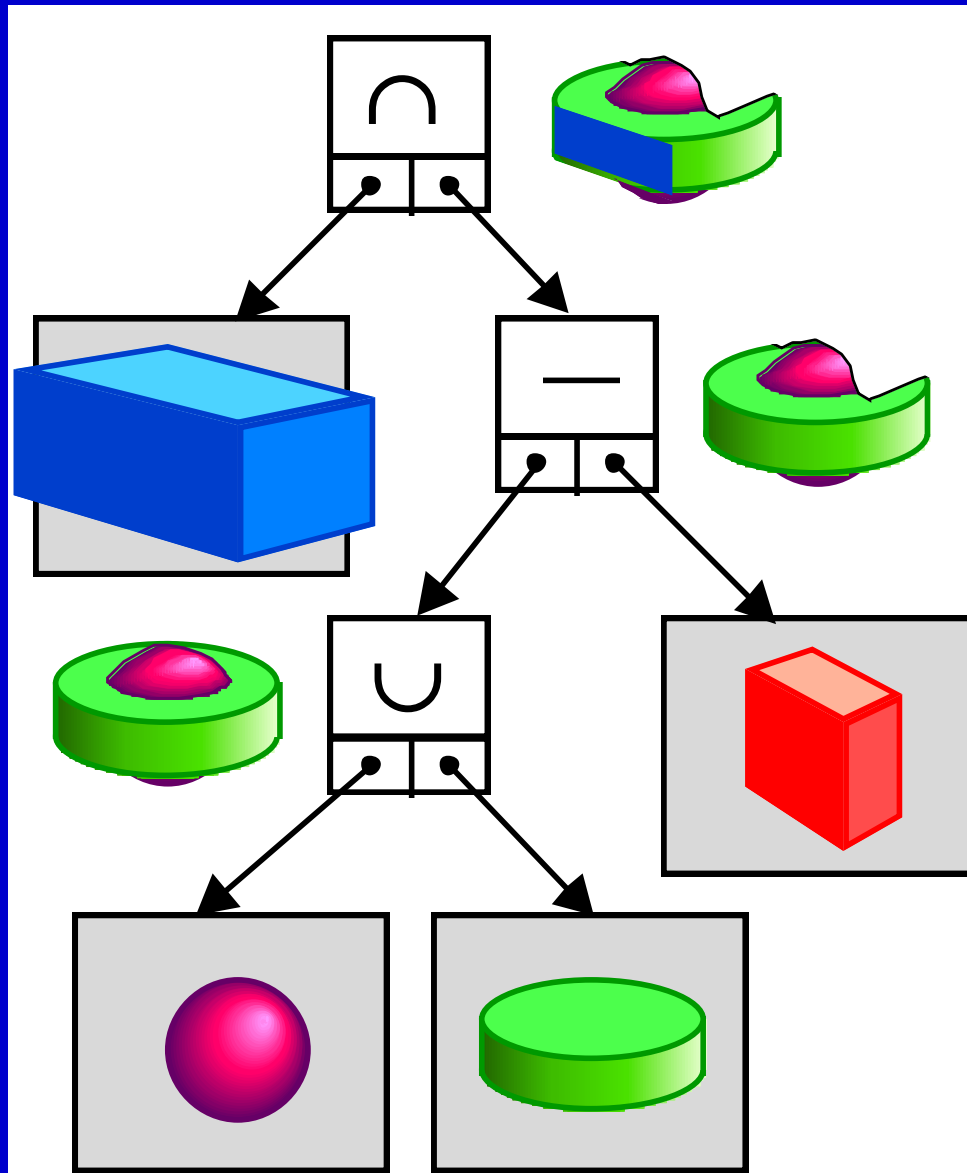
Constructive Solid Geometry

- Composition of primitives*
- Primitives: sphere, cone, cube, cylinder, ...*
- Operations: $+$, $-$, \cap , \cup , ...*
- 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.*

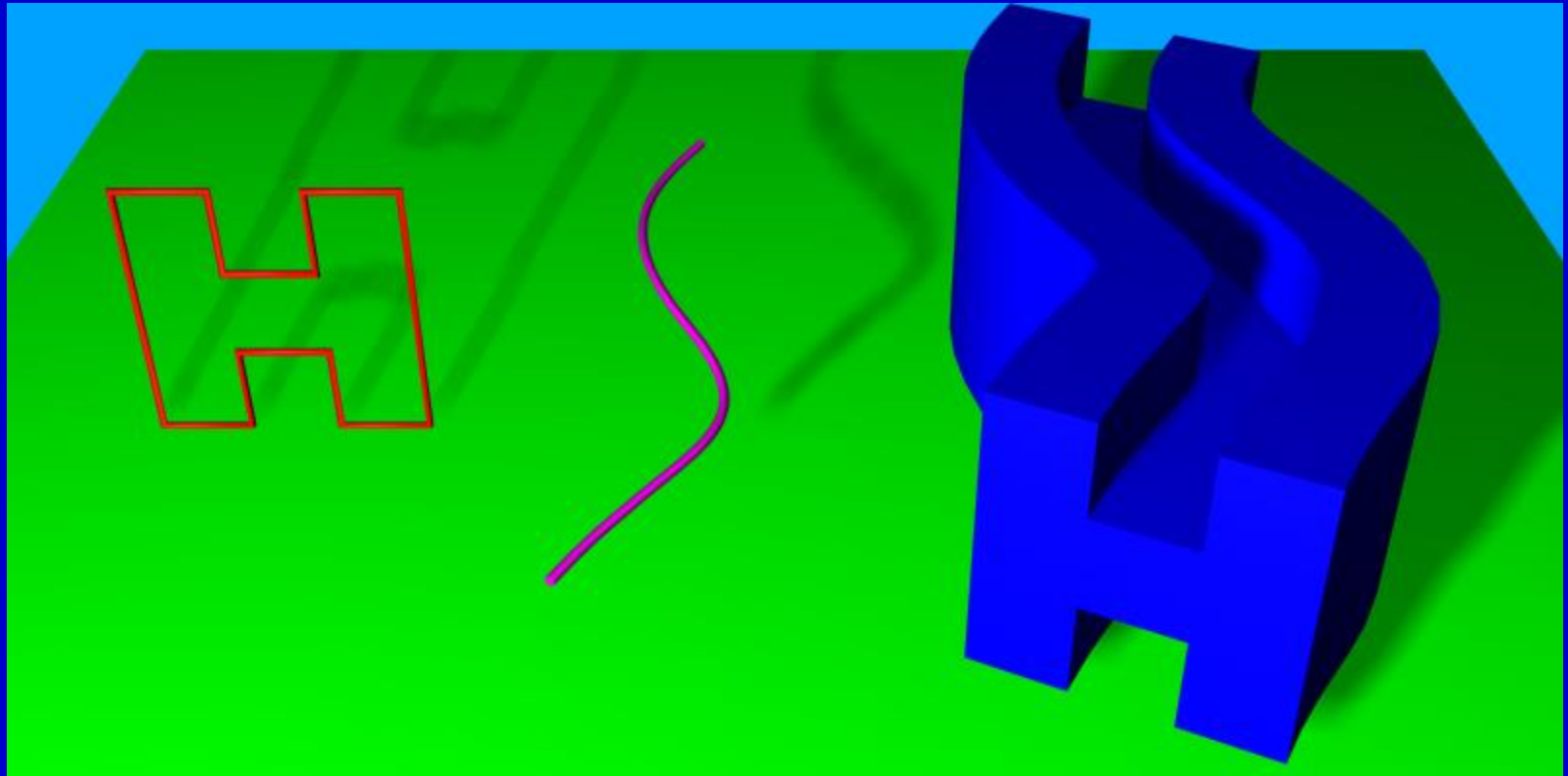
Forms:

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

Translational Sweep

Method:

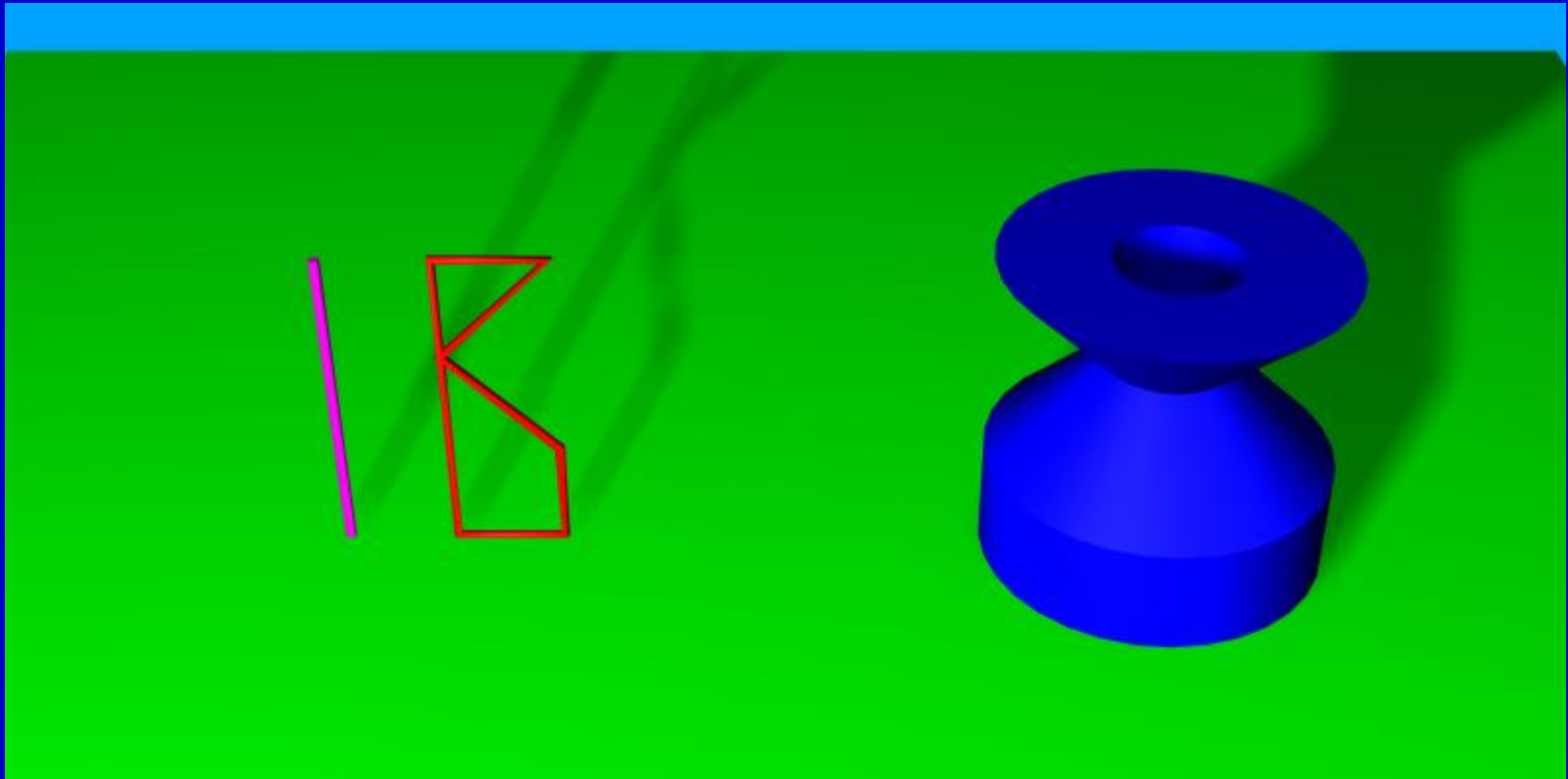
*Define the object with the contour (2D)
and the path.*



Rotational Sweep

Method:

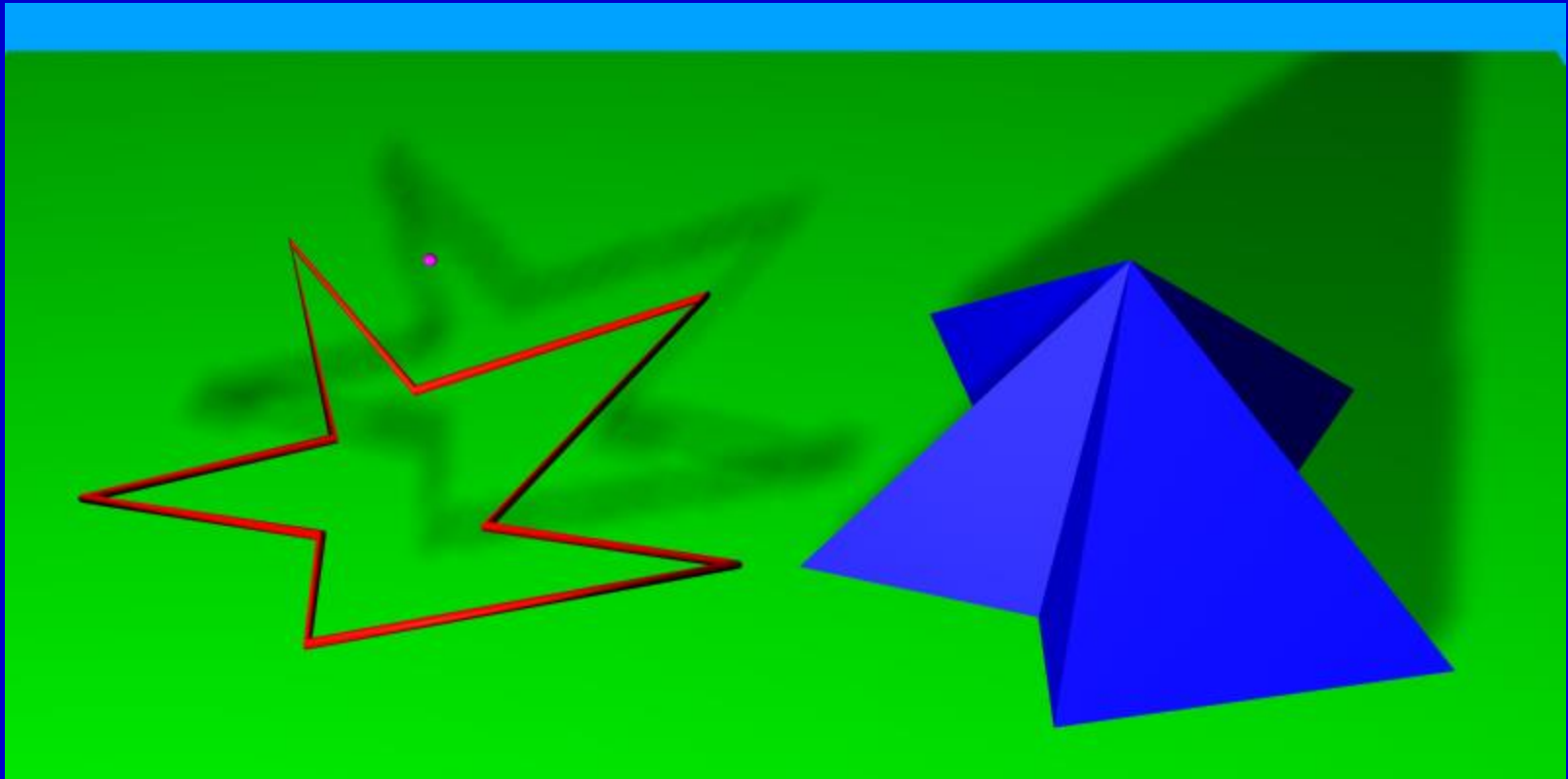
Define the object by rotating of the contour (2D) with the arbitrary axis.



Conical Sweep

Method:

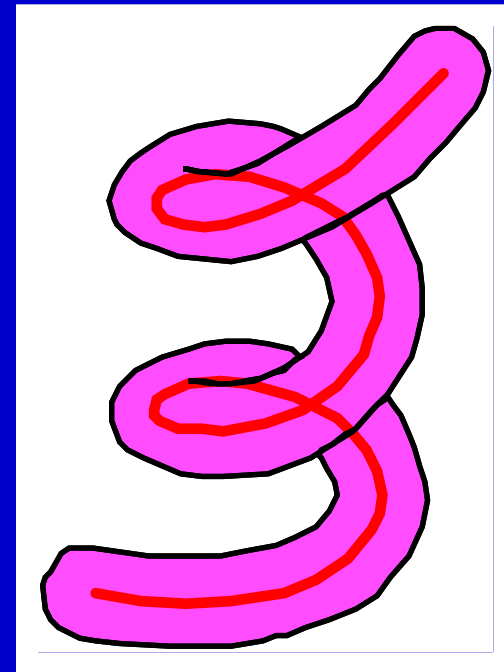
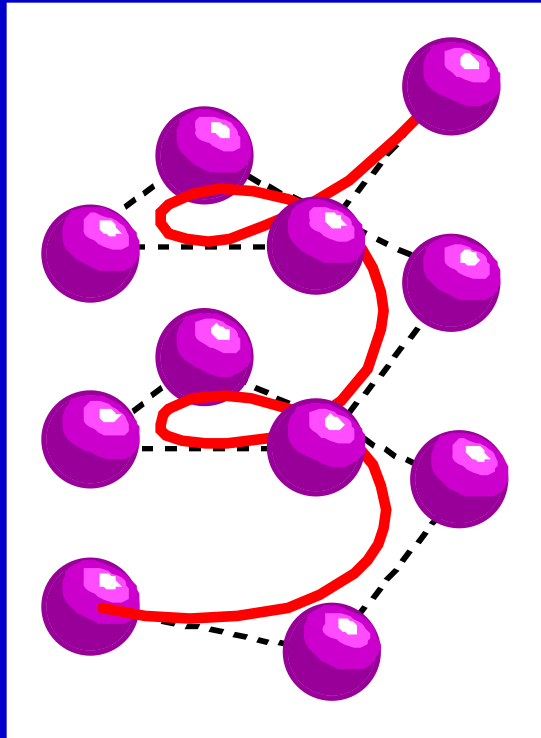
Define the object by the contour (2D) and a 3D-point (top of the pyramide).



Sphere Sweep

Method:

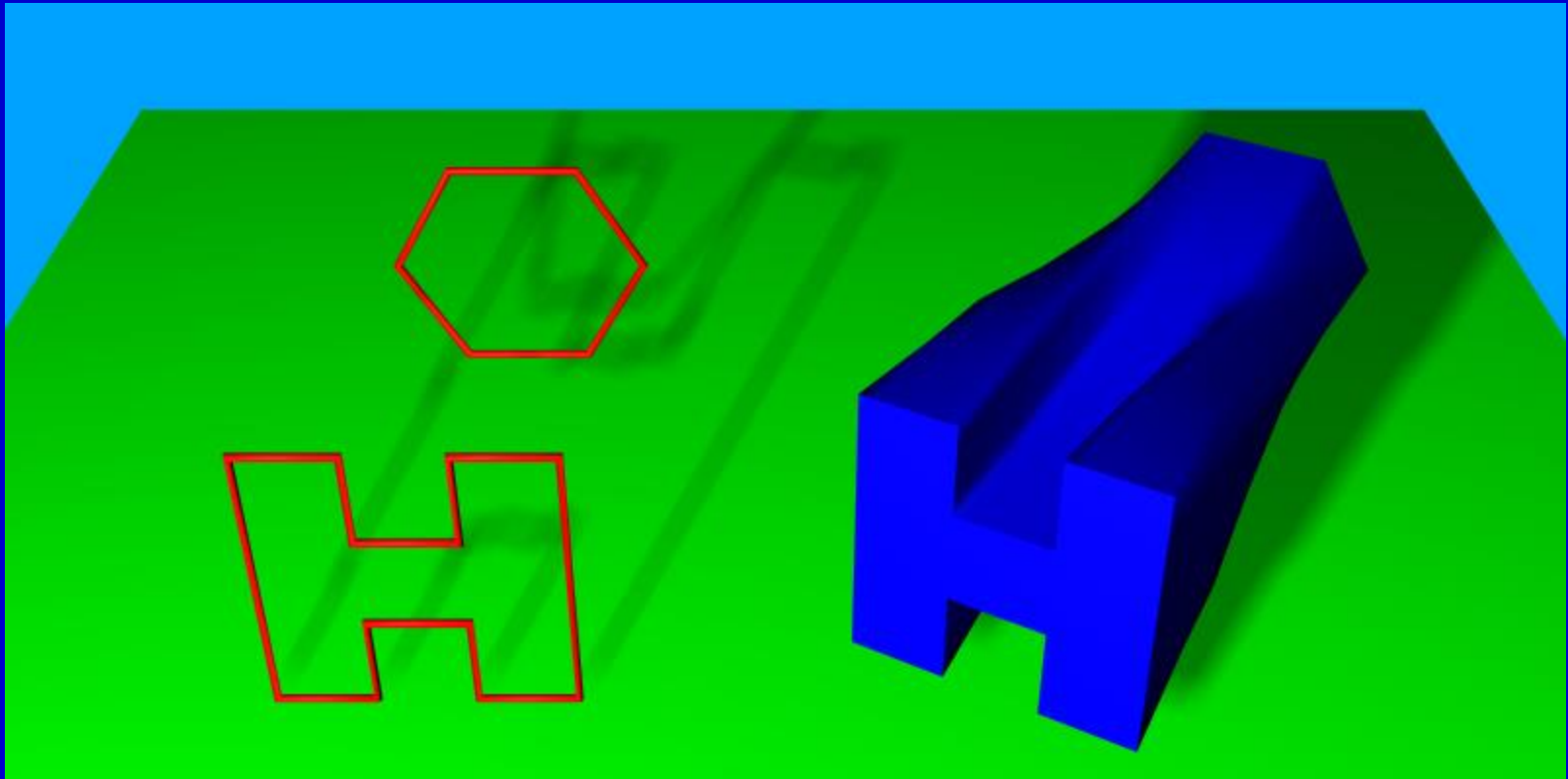
Define the object by the sphere with the varying radius and a path.



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

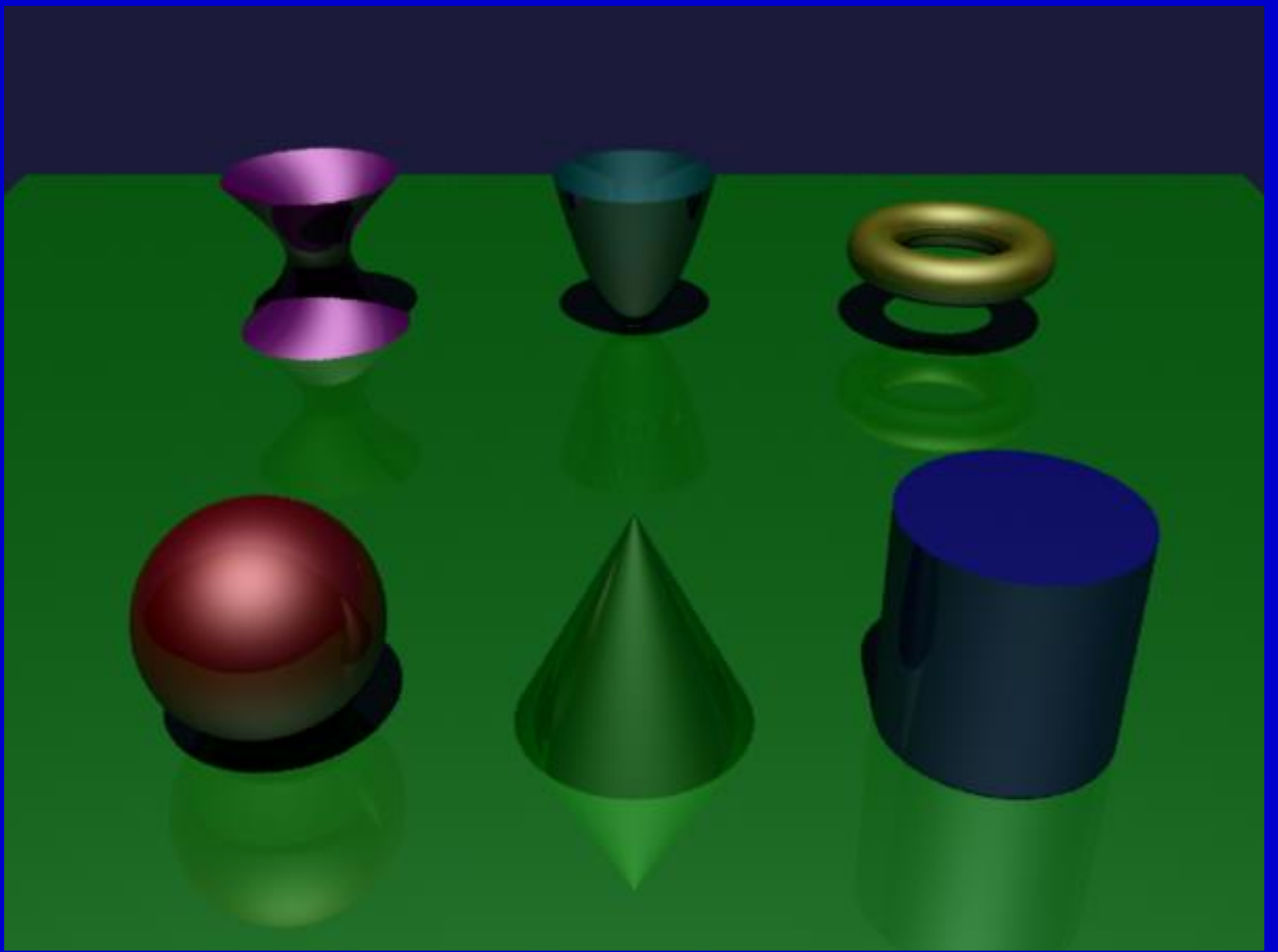
– *parametric:* $x = r \cos \alpha \cos \beta$

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

$$z = r \sin \alpha$$

Quadrics (examples)

- **Sphere:** $x^2 + y^2 + z^2 = r^2$
- **Cylinder:** $x^2 + y^2 = r^2 \quad 0 \leq z \leq \text{height}$
 $x^2 + y^2 \leq r^2 \quad z = 0 \text{ and } z = \text{height}$
- **Conic:** $x^2 + y^2 = z^2 \quad 0 \leq z \leq \text{height}$
 $x^2 + y^2 \leq z^2 \quad z = \text{height}$
- **Torus:**
 $(x^2 + y^2 + z^2 + R^2 - r^2)$
 $-4(x^2 + y^2) = 0$



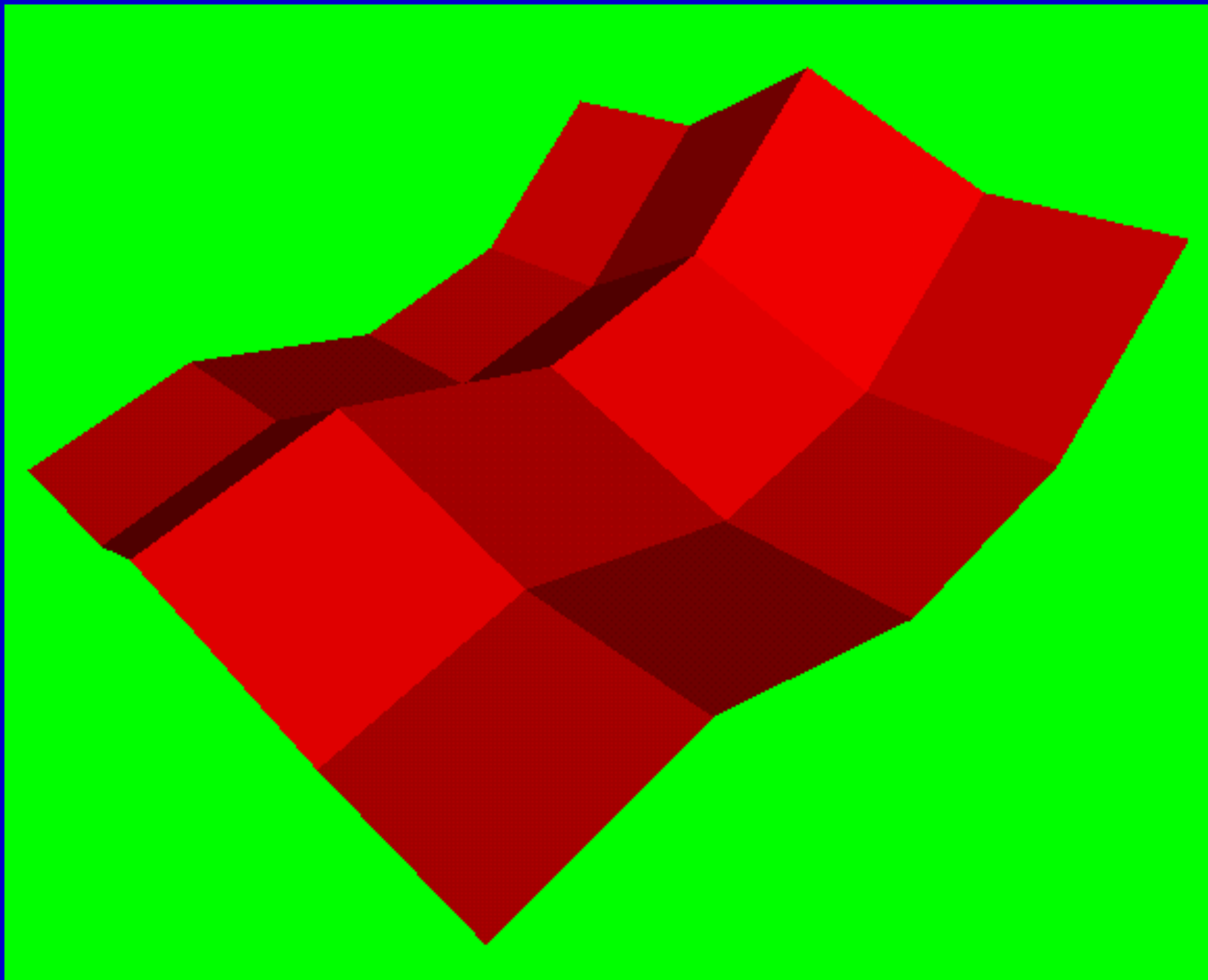
Terrain

Definition:

- Given the equidistant grid in the plane and in gridpoints the heights (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:

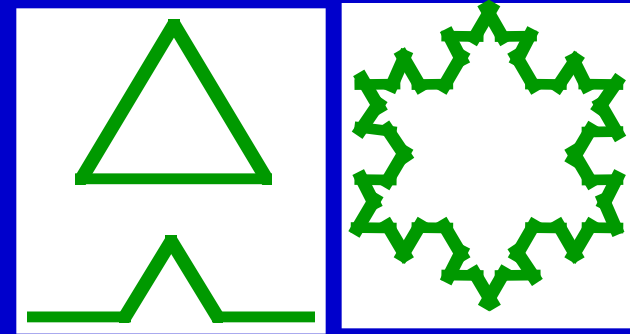
- If the surface of terrain or swept solid can be addressed by 2 parameters, we speak about 2.5D objects.*

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:

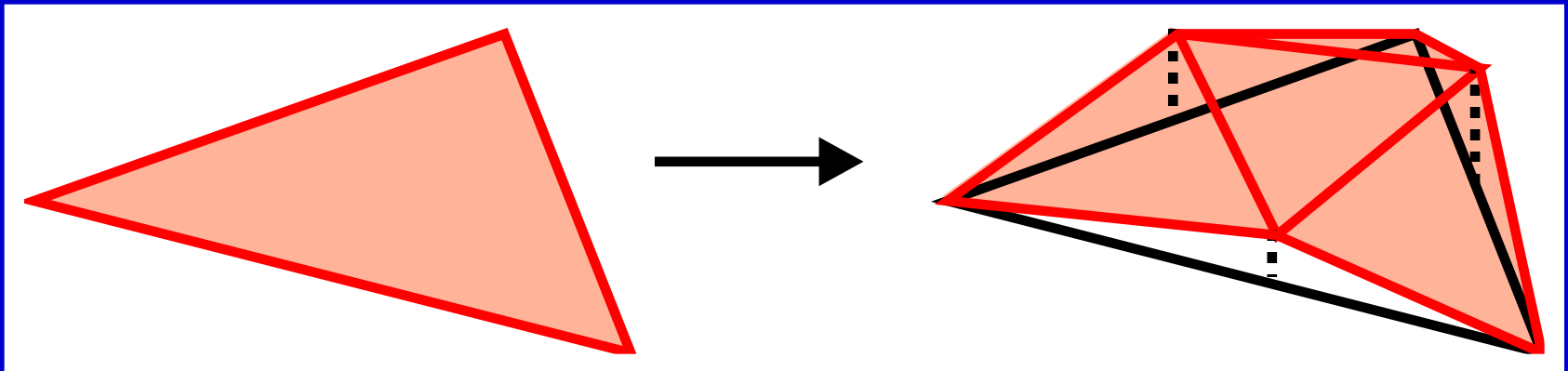
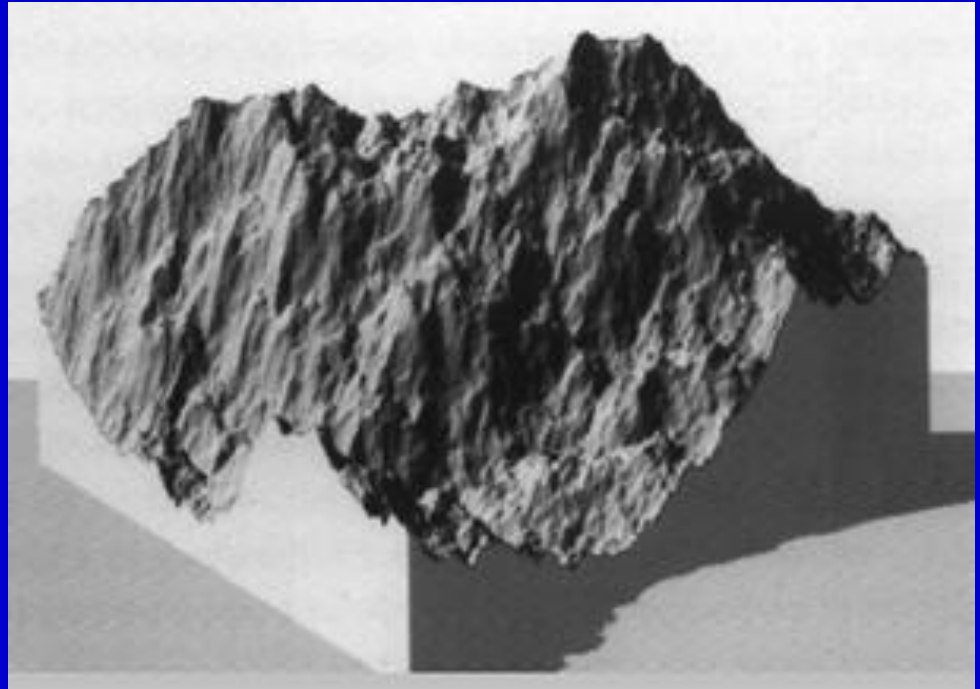
- **Generator** no more regular, but random one within the given borders Grenzen.
- **Initiator:** 1 triangle (or 2)
- **Generator:** each edge divide by a randomly generated point.

Fractal Mountains (algorithm)

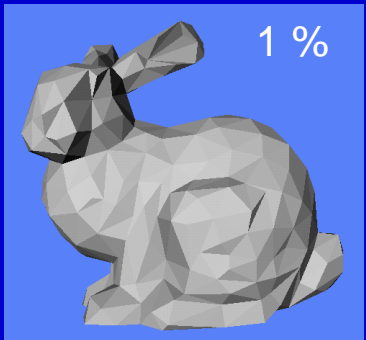
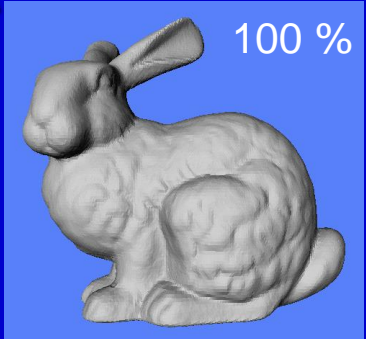
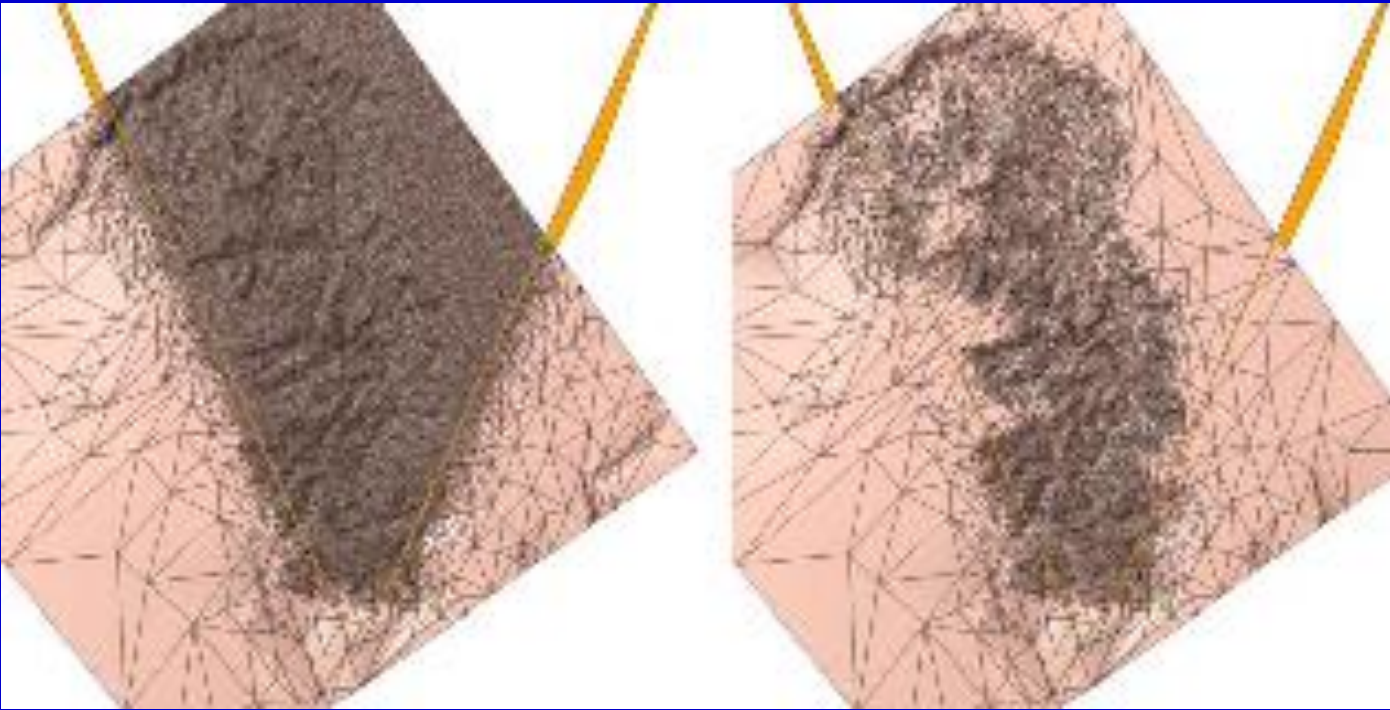
Each Step:

from 1 triangle
generate 4 new
ones.

Subdivide until the
Quality suffices.



Multiresolution, Area Subdivision Oscar Winning Animations



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