7M836

Animation & Rendering

Introduction, color, raster graphics, modeling, transformations

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Purpose

- Understand 3D computer graphics principles
  - Terminology
  - Basic algorithms
  - Complexity
- Get better results using modern animation and rendering packages

7M836

- Lectures
- Exercises
- Assignments

- http://www.ds.arch.tue.nl/7M836/

Contents

1. **Introduction**
   Computer graphics, color, raster graphics, graphics pipeline, geometric modeling, transformation.
2. **Viewing and visible surface determination**
   Viewing, clipping, projection, visible surface determination
3. **Illumination and shading**
   Light sources, reflection, shading
4. **Ray tracing**

Contents

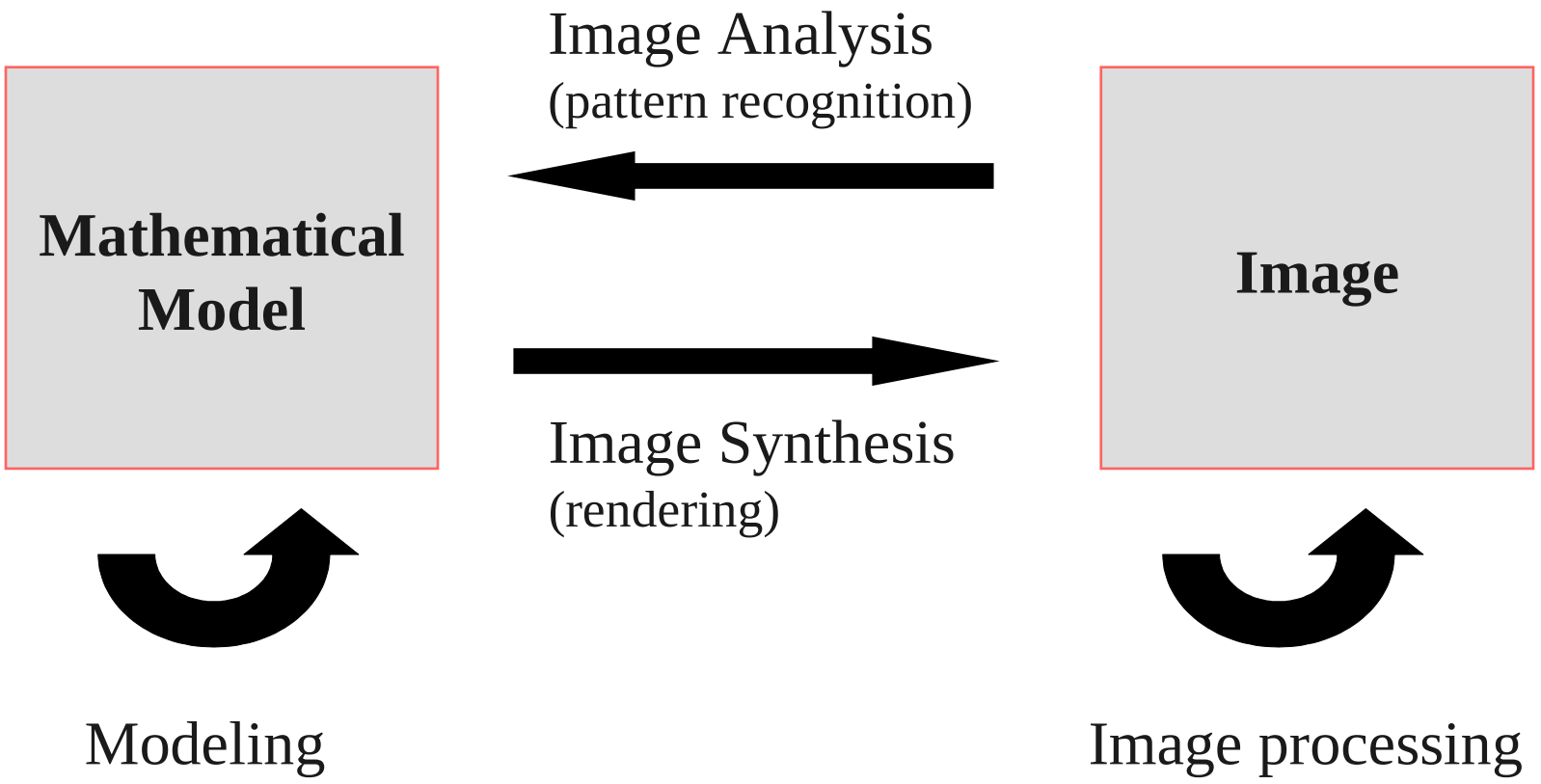
5. **Radiosity**
6. **Mapping techniques**
   Texture mapping, bump mapping, environment mapping, aliasing
7. **Animation**
   Animation process, keyframe animation, forward and inverse kinematics
8. **Examples and virtual reality**

Literature

- Computer Graphics – Principles and Practice (second edition)
  Foley, van Dam, Feiner, Hughes
- 3D Computer Graphics
  A. Watt
- Advanced Animation and Rendering Techniques: Theory and Practice
  A. Watt, M. Watt
- 3D Graphics : A Visual Approach
  R.J. Wolfe

- and many more

Computer graphics



Supporting disciplines

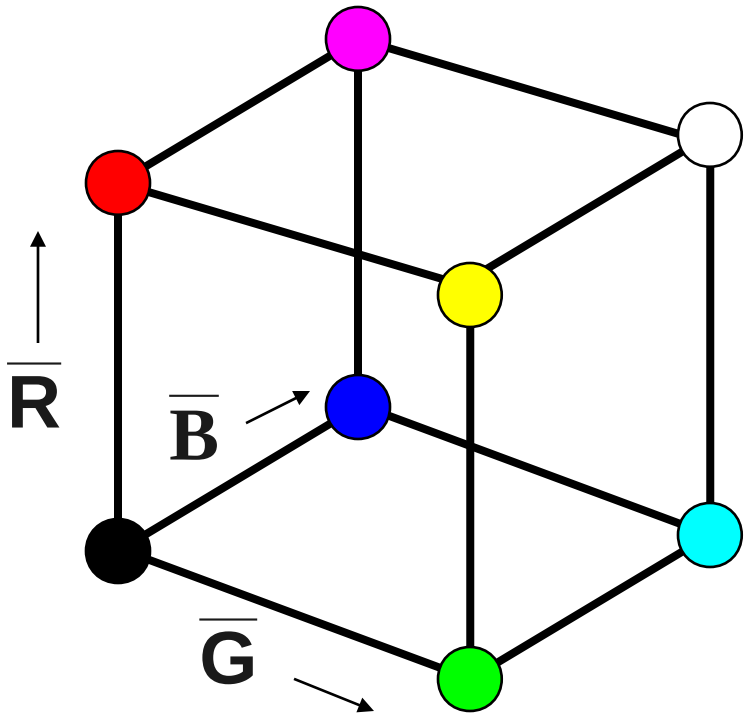
- Computer science
  - algorithms, data structures, software engineering, …
- Mathematics
  - geometry, numerical, …
- Physics
  - optics, mechanics, …
- Psychology
  - color, perception
- Art and design

Color models

- RGB red, green, blue
- HSV hue, saturation, value

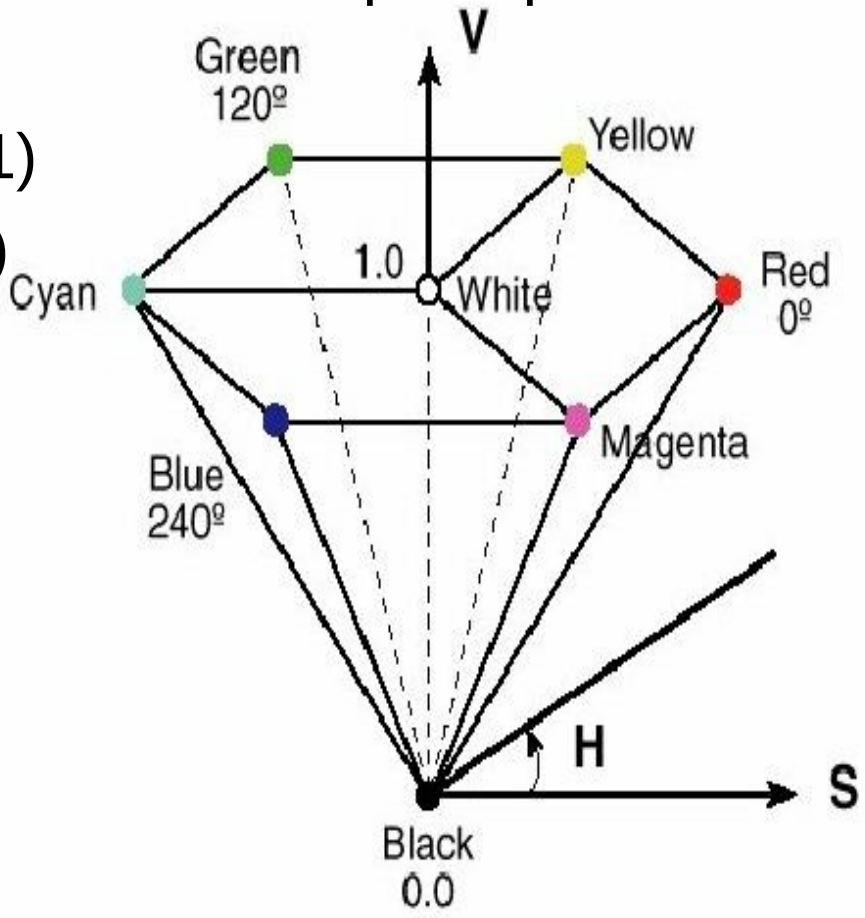
RGB-model

- 3 primary colors: **red**, **green**, and **blue**
- Color cube:
  - Color = point in cube
- Additive:
  - $\overline{\mathbf{C}} = r\,\overline{\mathbf{R}} + g\,\overline{\mathbf{G}} + b\,\overline{\mathbf{B}}$



HSV-model

- More user oriented: based on intuitive perception
  - **Hue**: tint (0-360°)
  - **Saturation**: shade (0-1)
  - **Value**: brightness (0-1)
- Color is point in cone

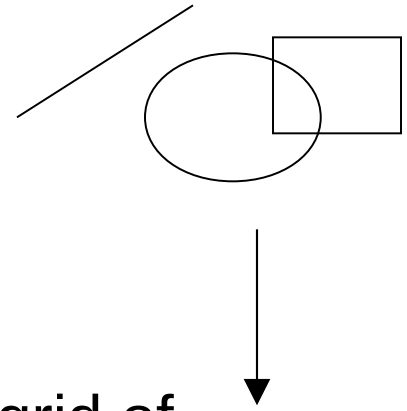


Color models

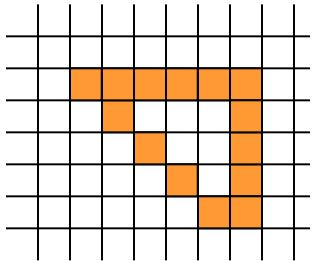
- Limitation of color models, such as HSV and RGB:
  - No linear relation with perception.
    At some places in RGB cube a small step results in a visual change, while at other places it does not.
  - Color models describe the colors a monitor can display. That is only a subset of what a human can see.

Computer graphics

- Vector graphics
  - Image is represented by continuous geometric objects: lines, curves, etc
  - Exact, scalable
  - Diagrams, schemes, ...
  - Examples: PowerPoint, CorelDraw, ...



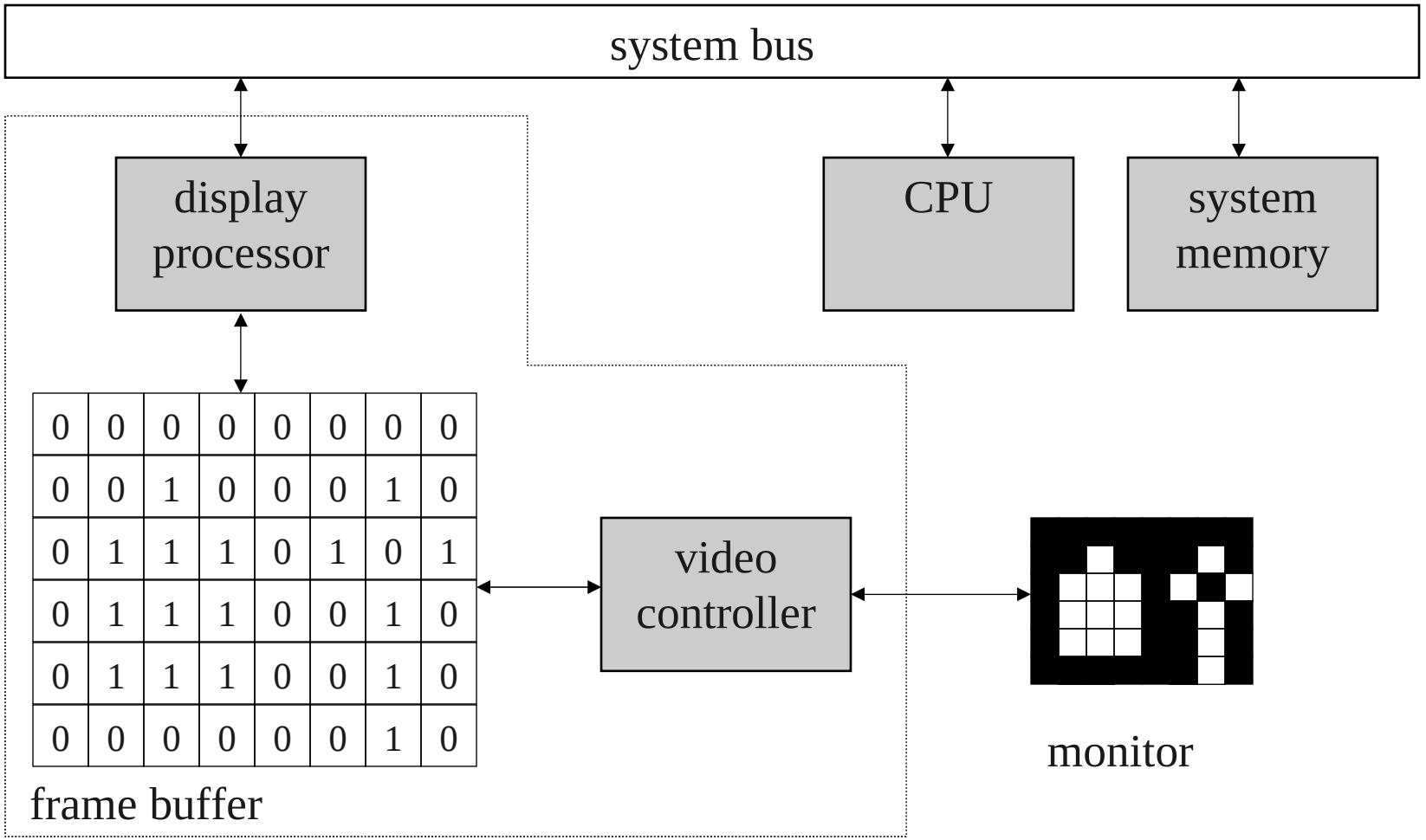
- Raster graphics
  - Image is represented as an rectangular grid of (coloured) squares
  - Examples: Paint, PhotoShop, ...



Raster graphics

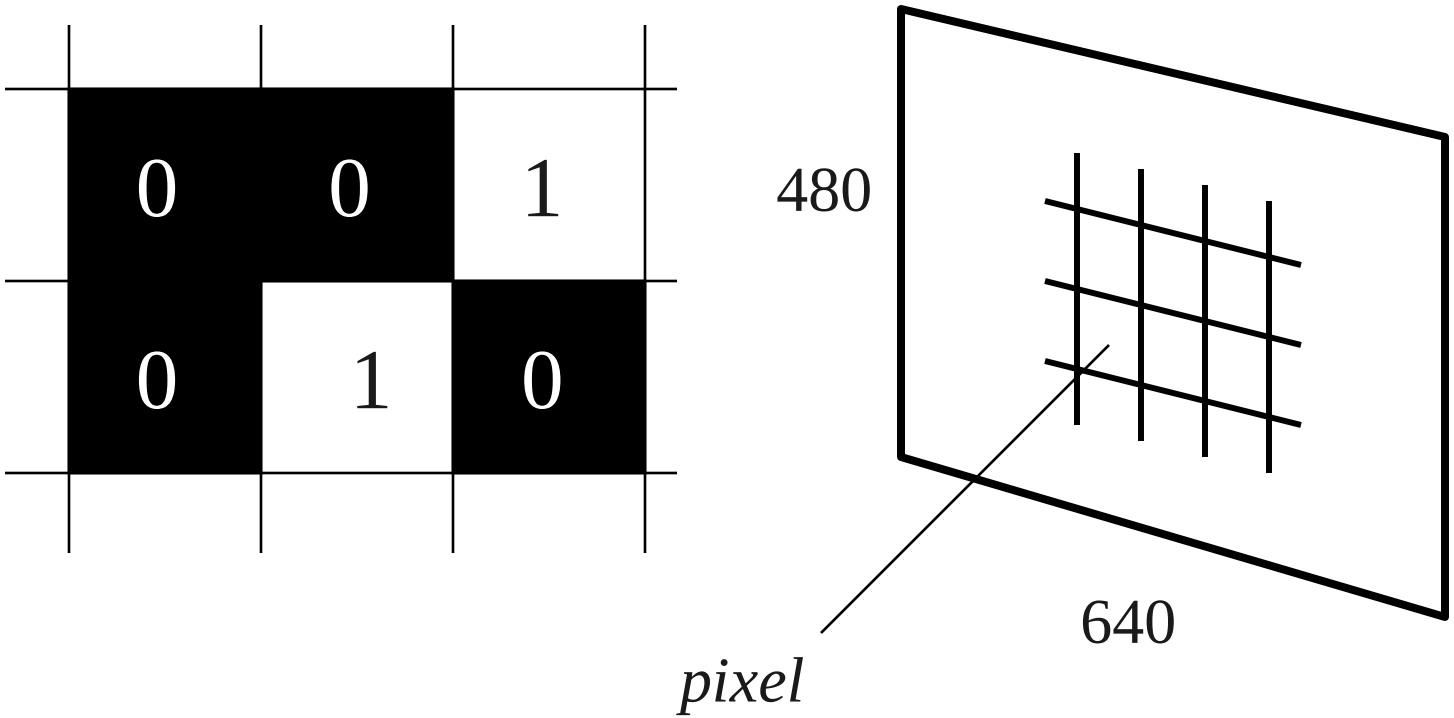
- Currently “standard” for computer graphics
- Screen is subdivided in grid of “squares”: *picture elements* or *pixels*
- Per pixel: *n* bits information
- Resolution: size of grid and number of bits per pixel

Raster graphics hardware



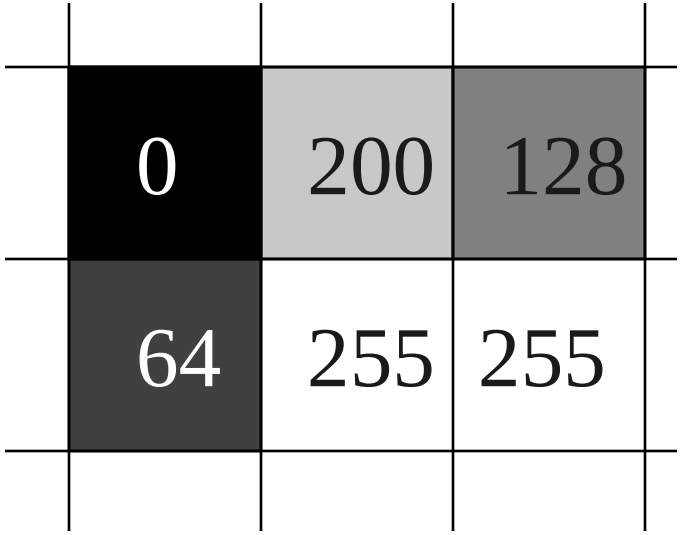
Raster display – 1 bit per pixel

- 0 = black, 1 = white



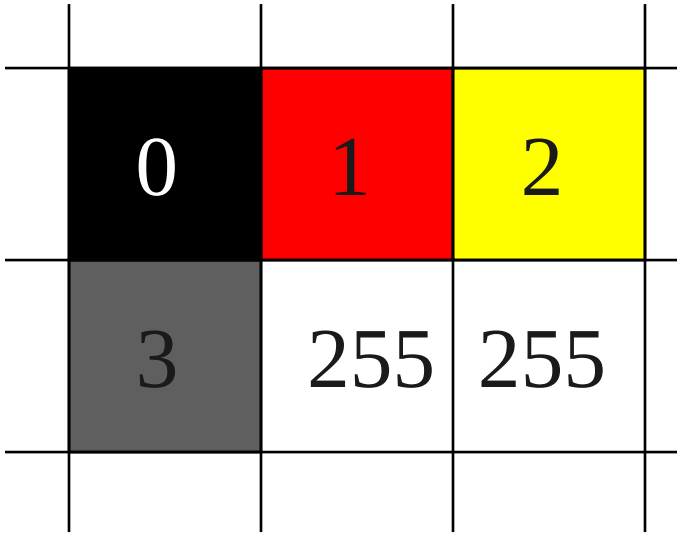
Raster display – 8 bits / pixel

- 256 gray values
- 0 (black) to 255 (white)



Raster display – 8 bits / pixel

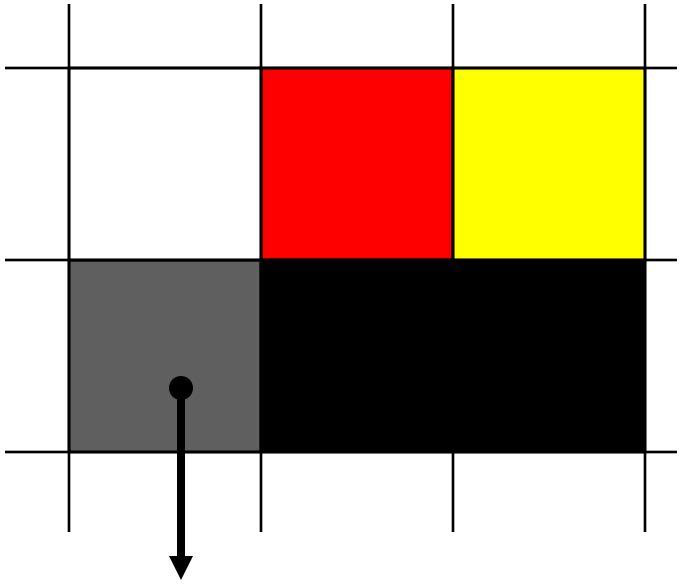
- 0 – 255: index in *color lookup table*
- Color lookup table contains 256 colors chosen from 16 million colors



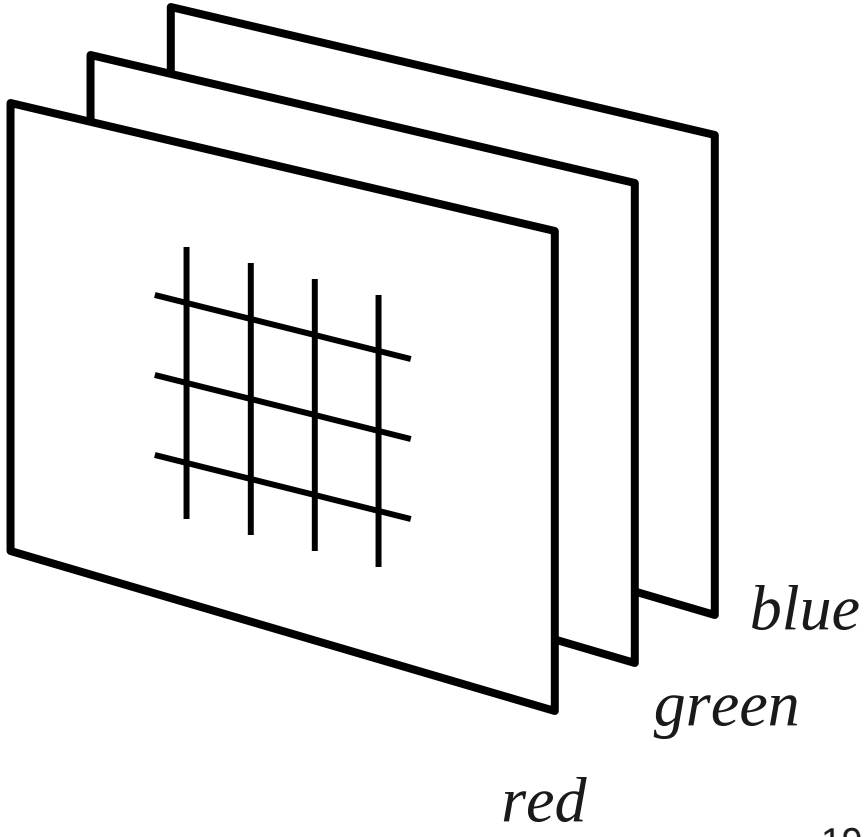
code	red	green	blue
0	0	0	0
1	255	0	0
2	255	255	0
3	128	128	128
...	...	...	...
255	255	255	255

Raster display – 24 bits / pixel

- Per pixel: red, green, and blue
- 16 million colors at the same time
- True color



128,128,128



File formats

	Number of colors	Size (uncompressed)	
1-bit	2 black/white	37.5 kb	
8-bit	256 gray values 256 color values (CLUT)	307.2 kb	GIF, (PNG)
24-bit	256x256x256 colors	921.6 kb	BMP, TGA, TIFF, JPEG
32-bit	256x256x256 colors 8 bits alpha plane	1228.8 kb	TGA
Vector			EPS, PS

File formats

Content image / purpose	Format
Many colors; continuous variation in colors (photo's) Storage	TIFF, TGA, BMP, PPM
Many colors; continuous variation in colors (photo's) Presentation	JPEG
Limited number of colors	GIF, PNG
Line drawings	PS, EPS

- File format conversion tool: *Irfanview*

Graphics Software

- Special-purpose packages
  - Photoshop, Powerpoint, AutoCAD, 3D Studio, Maya, ..
- Computer-graphics application programming interfaces (CG API)
  - Set of graphics functions used from programming language
  - Access to hardware
  - OpenGL, Direct3D, VRML, Java3D, ..

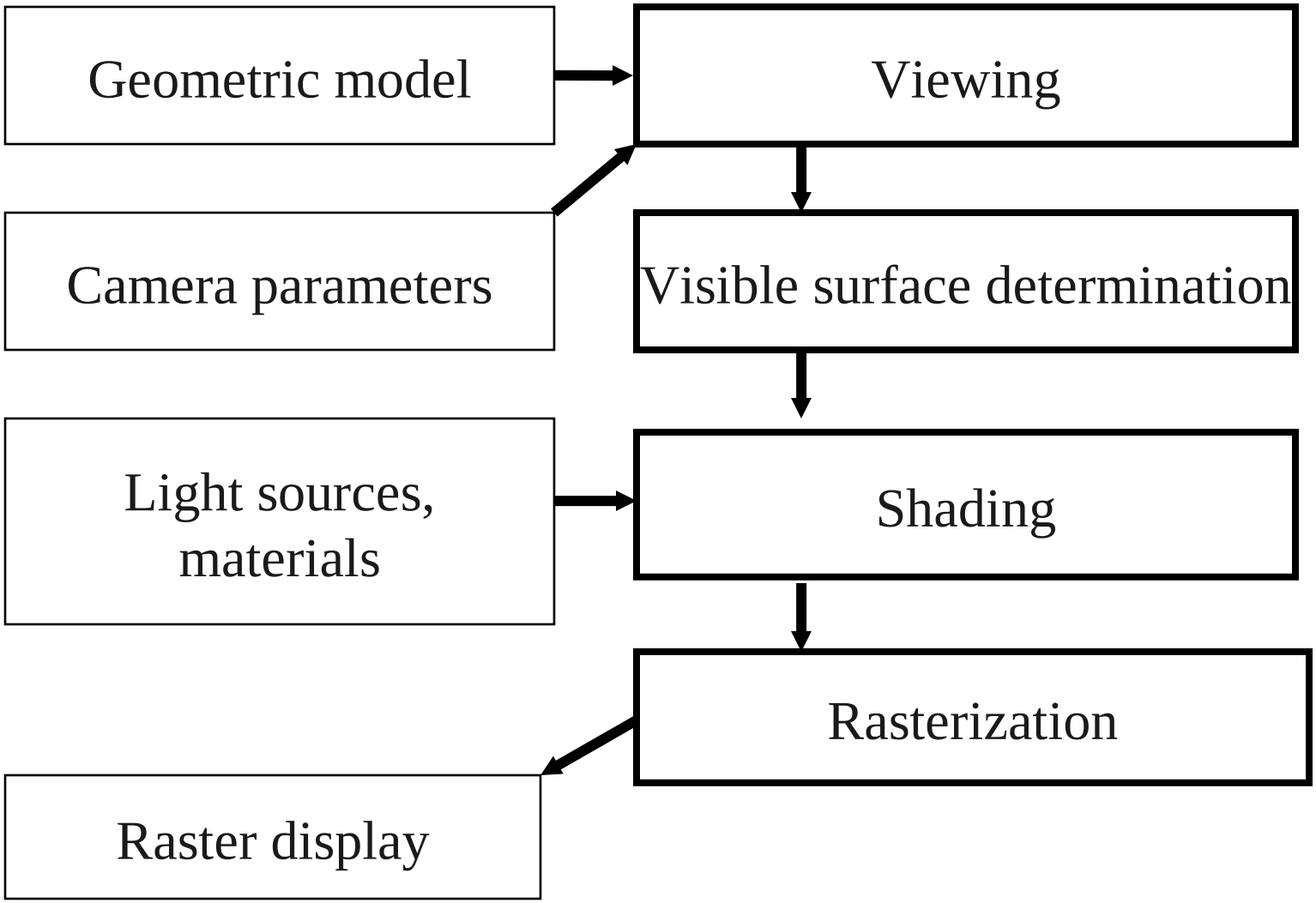
Rendering

- How do I generate a realistic image of a scene?
- Problems:
  - World is complex (shape, light, ...)
  - World is 3 dimensional, screen is 2 dimensional
  - ...

Problem subdivision

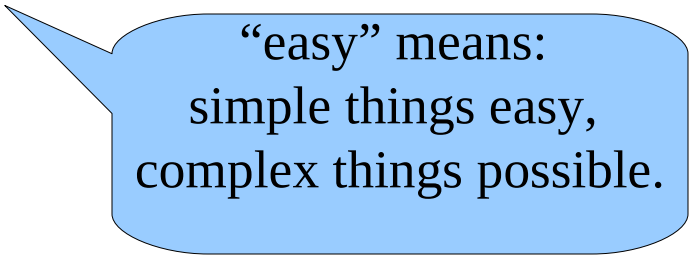
- Geometric modeling
  - How do we define the shape of an object?
- Projection and hidden surface removal
  - How do we determine what is visible on screen and what is not?
- Shading
  - How do we model color, texture, and contribution of light?
- Rasterization
  - How do we determine pixel values ?

Graphics pipeline



Geometric modeling

- World contains all kind of objects
  - Trees, humans, buildings, clouds, mountains, waves, fire, plants, …
- Describe objects in a way that
  - (user) input is easy
  - processing is easy
  - display is easy



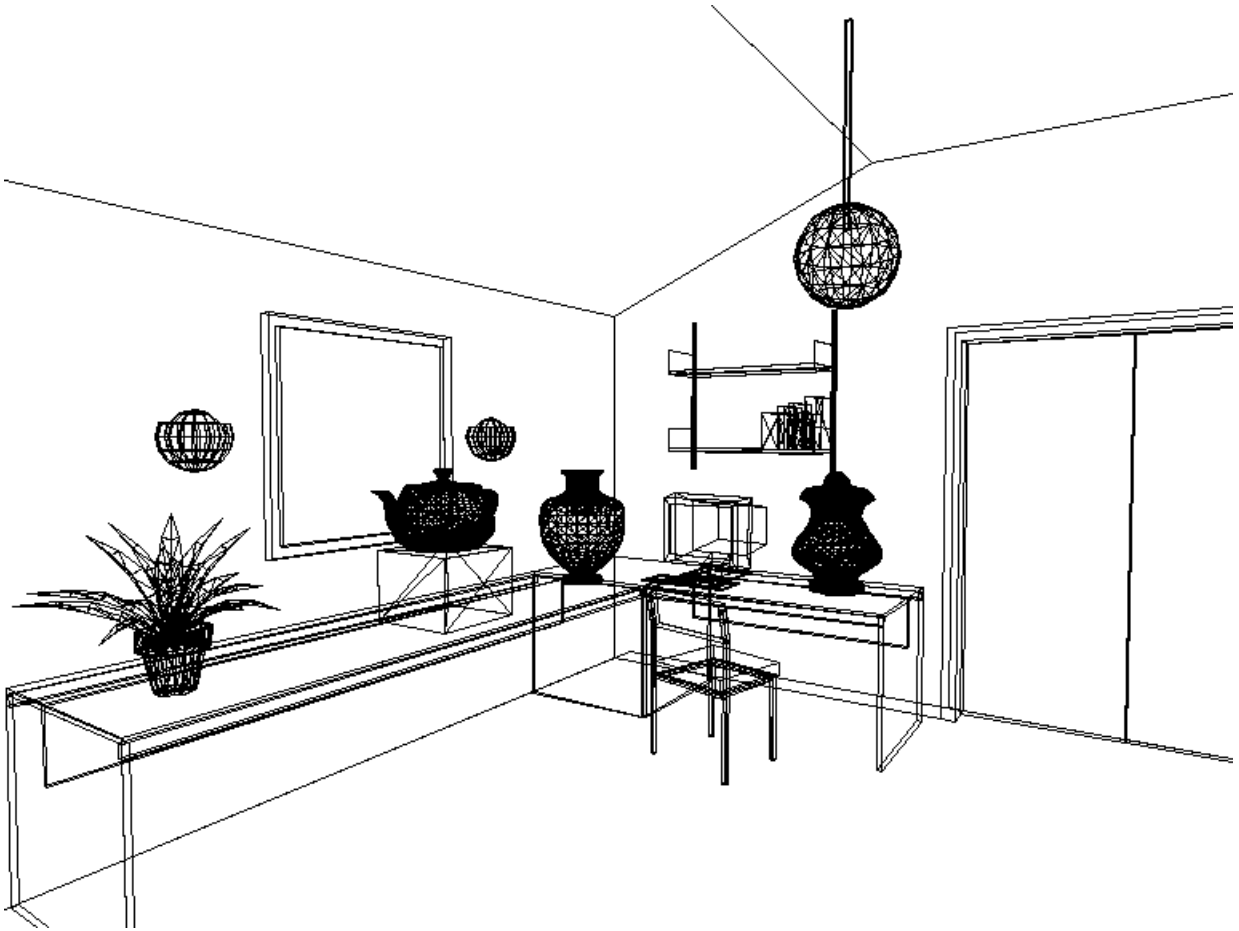
Geometric modeling

- Examples
  - Wireframe
  - Procedural
  - Polygons
  - Constructive solid geometry
  - Curved surfaces
  - Ad hoc techniques

Wireframe

- Model is sequence of lines connecting points
- No information on surface/faces available, therefore
  - No visibility information
  - no *shaded images* possible
- Face information cannot be deduced automatically

Wireframe



Procedural

- Shape defined by type and parameters
- Program interprets definition
- Examples
  - Type = sphere, position = [3, 4, 5], radius = 2
  - Type = oak, age = 10 years
- Compact, easy input, tailored to application
- Often internal conversion to other representation

We will use this in the exercises with PovRay.

Polygons

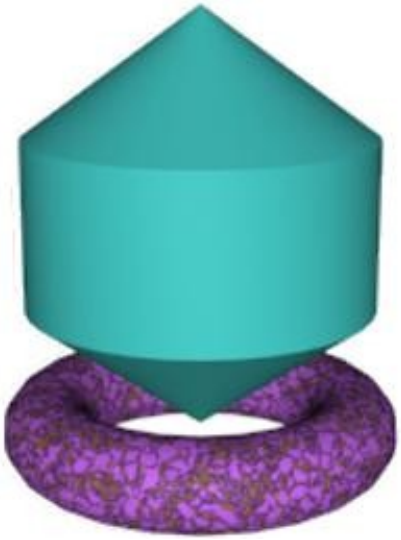
- Polygon consists of three or more points lying in a plane (often triangle)
- Model is collection of polygons
- Input and change of model is laborious
- Very well suited for hardware
- Often used as end representation

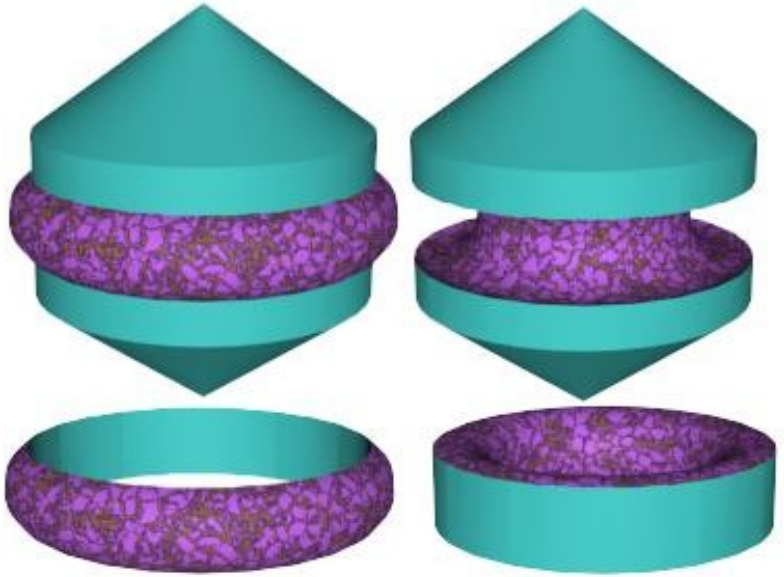
Polygons

Constructive solid geometry

- Model is defined by hierarchy of Boolean operations on standard shapes, such as cube, sphere, cylinder, cone, and torus
- Boolean operations
  - union, difference, intersection
- Useful for input, e.g. in mechanical engineering
- Often, conversion to other representation needed before model is rendered

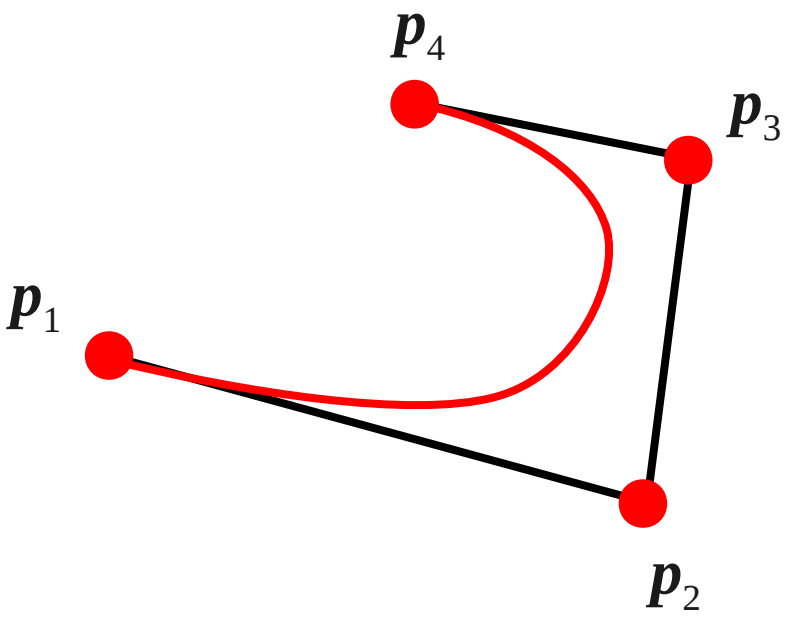
Constructive solid geometry





Curved surfaces

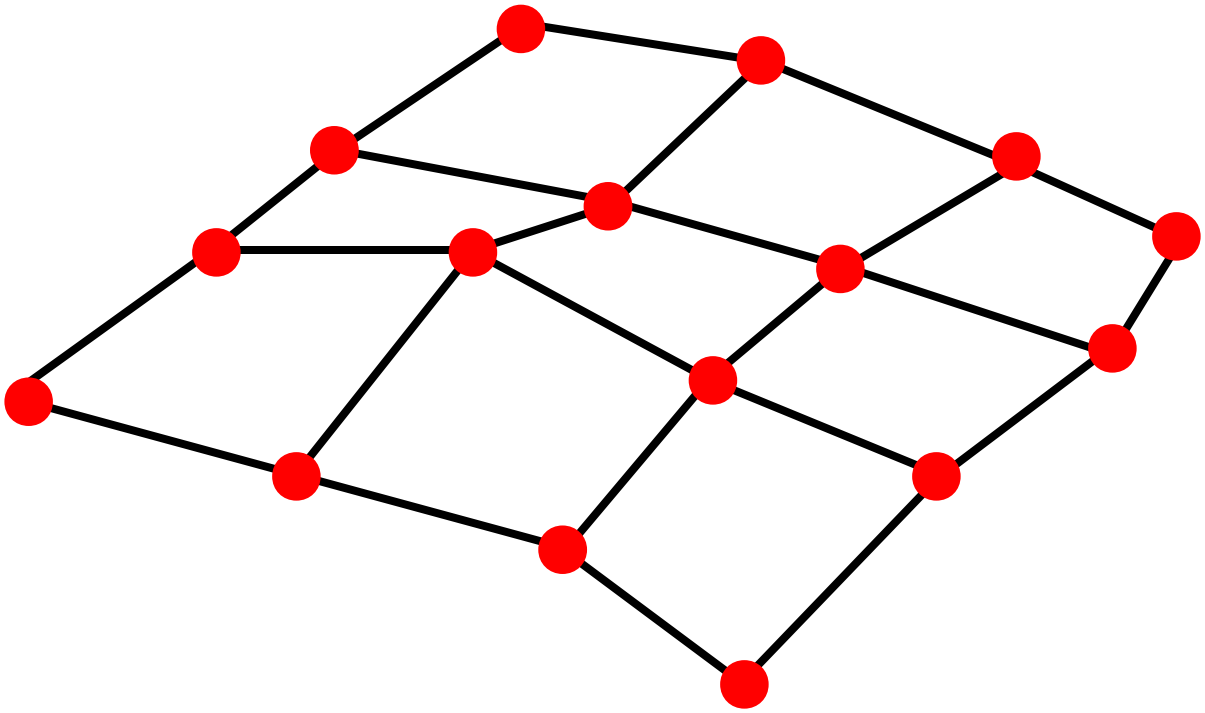
- Smooth curve defined by sequence of control points



$$\boldsymbol{p}(t) = (1-t)^3\,\boldsymbol{p}_0 + 3(1-t)^2 t\,\boldsymbol{p}_1 + 3(1-t)t^2\,\boldsymbol{p}_2 + t^3\,\boldsymbol{p}_3$$

Curved surfaces

- Smooth surface defined by grid of control points
  - Bézier surfaces
  - NURBS
  - ..



The Utah teapot

Curved surfaces

- Very useful for modeling, e.g. in car industry, but also in cartoon animation
- Often conversion to other representation (polygons) before model can be rendered

Ad hoc techniques

- Mountain shapes: wrinkled shapes (fractals)
- Firework: particles
- Plants: Lindenmayer systems
- Hair and fur
- Fabric en clothing
- Clouds
- …

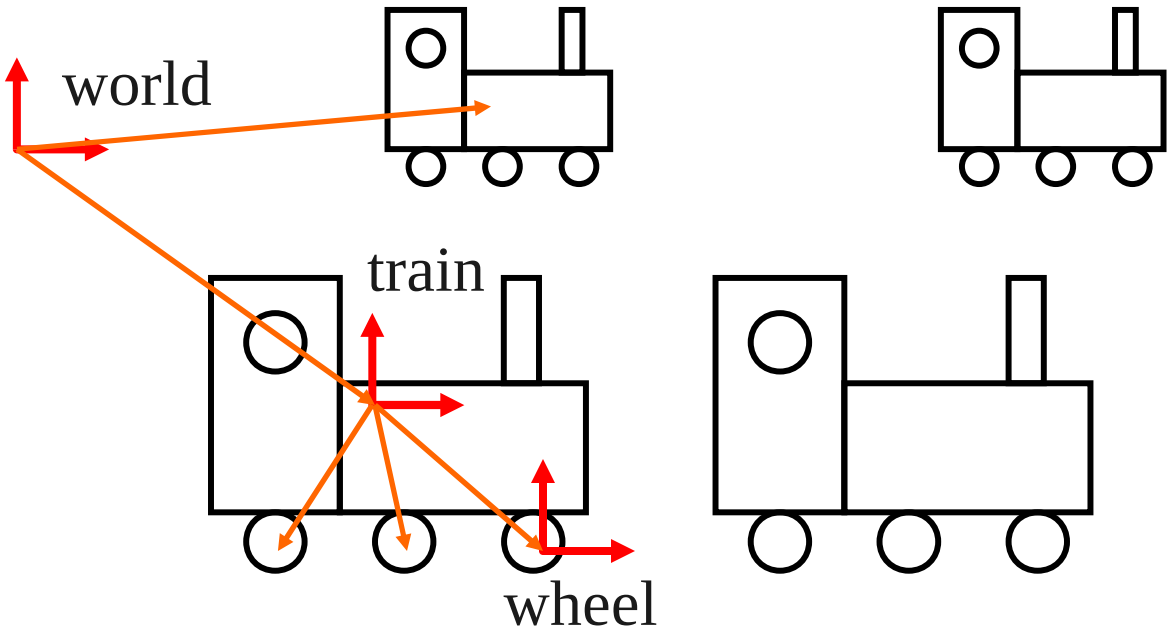
Geometric modeling

- Input: Computer Aided Design (CAD) system
- Convenient for input:
  - Curved surfaces, CSG, procedural representations
- Appropriate for computer processing/display:
  - Polygons, points, lines

Modeling-transformations

- Besides shape, *position, orientation, and scale* of objects in a scene is important
- Often, model consists of several parts that are positioned relatively to each other

Coordinate systems



Modeling-transformations

- Complete model (scene) specified in world coordinates

- Objects within model specified in object coordinates
- Transformation positions object into world

- Object may contain sub-objects that are specified in their own local coordinates
- Transformation positions sub-object into object

- Hierarchical model

Example

- World contains (for instance) human figure
- Human figure is built from:
  - torso + head + arm + arm + leg + leg + ..
- Arm is built from:
  - upper arm + lower arm + hand + ..
- Etc.

Graphics pipeline