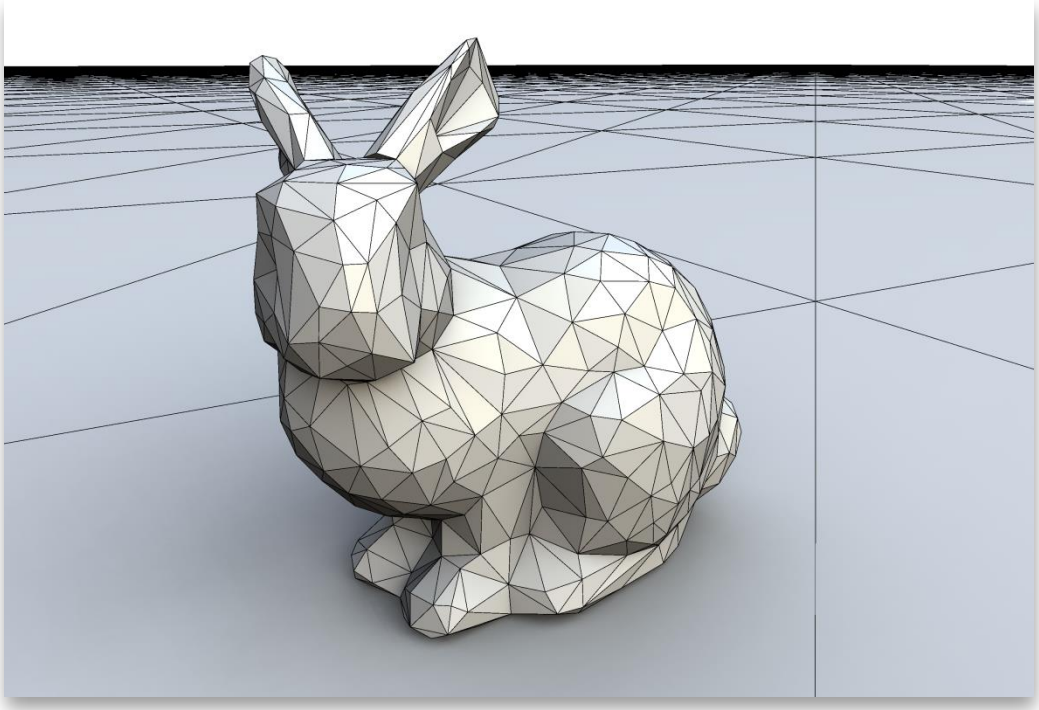
Graphics 2014



Introduction

[Faculty of Science]
Information and
Computing Sciences

Universiteit Utrecht

Computer Graphics

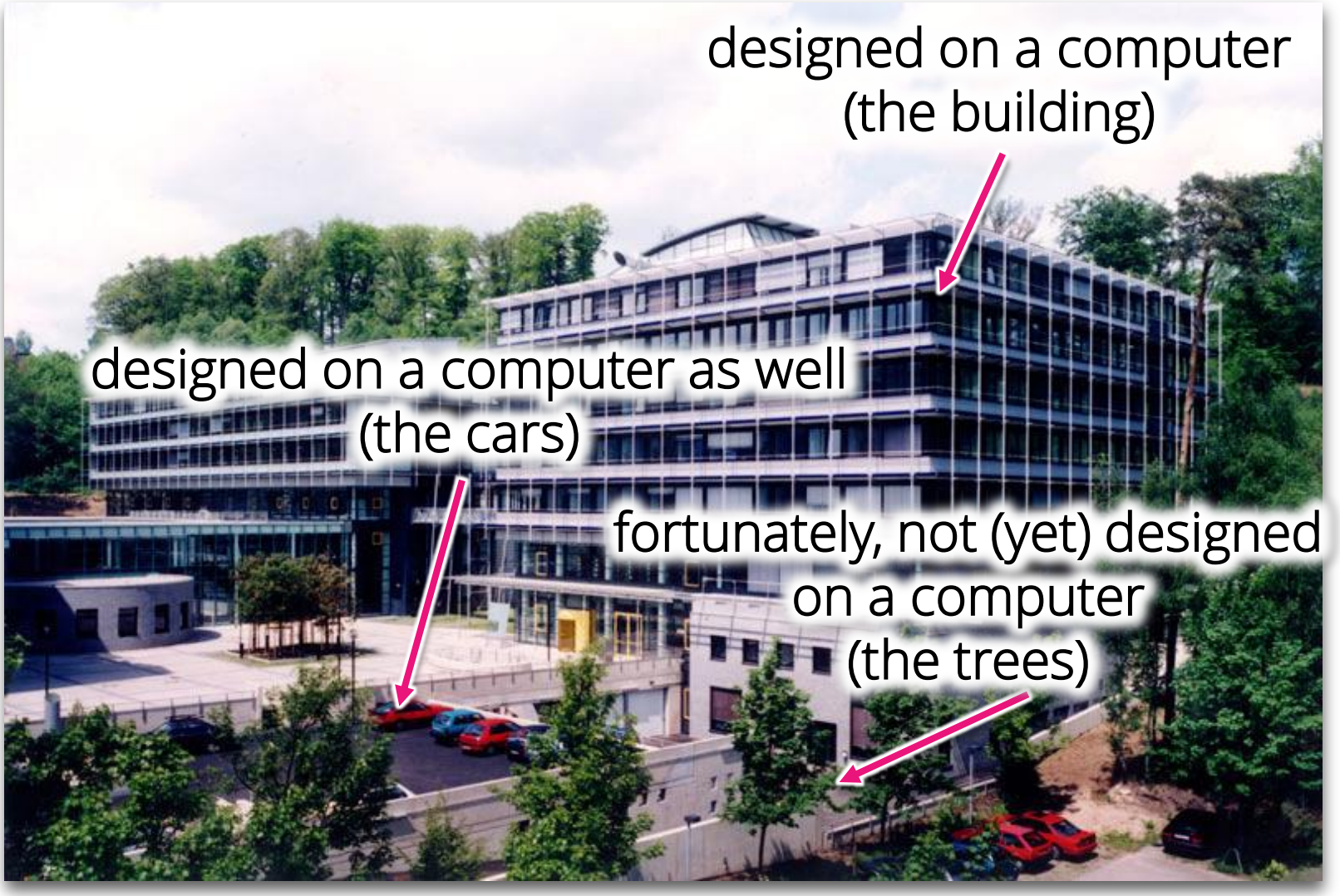
Different Types of Graphics

CAD / CAM

- Precision Guarantees
- Geometric constraints (e.g. exact circles)
- Modeling guided by rules and constraints

[aimatshape.net]

The Modern World…

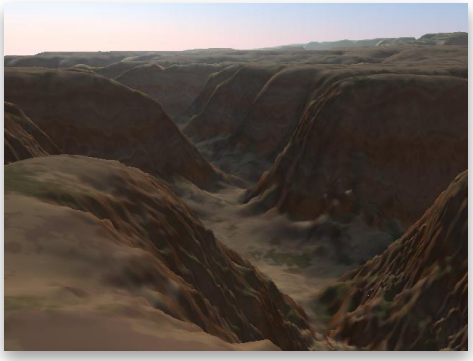


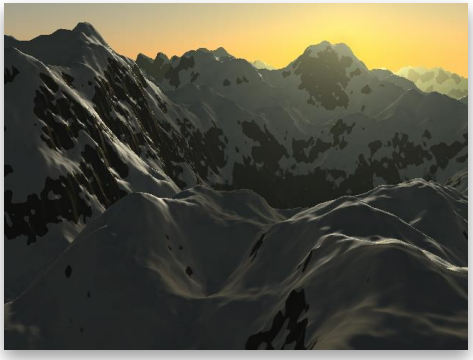
[c.f. Danny Hillis, Siggraph 2001 keynote]

Different Types of Graphics

Games & Movies

- Has to “look” good
- Natural Phenomena
- Ad-hoc techniques are ok
- For example:
  textures & shaders
  to “fake” details
- More complexity, but
  less rigorous



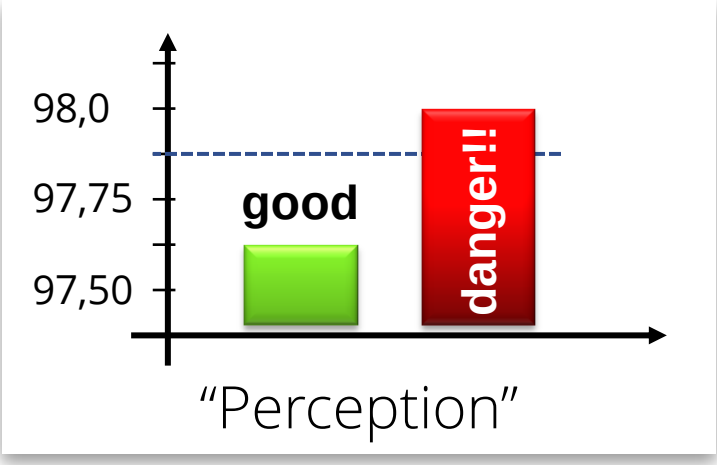


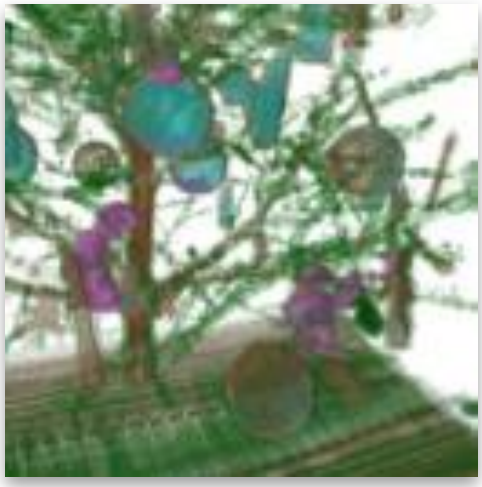
[M. Bokeloh et al., I3D 2006]

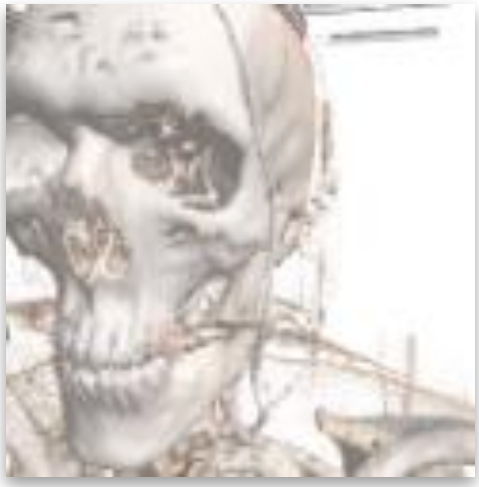
Different Types of Graphics

Scientific Visualization

- Understanding data
- Simulation, medicine, empirical sciences, …
- Focus on analysis or presentation of insights
- Human perception plays a role, too.





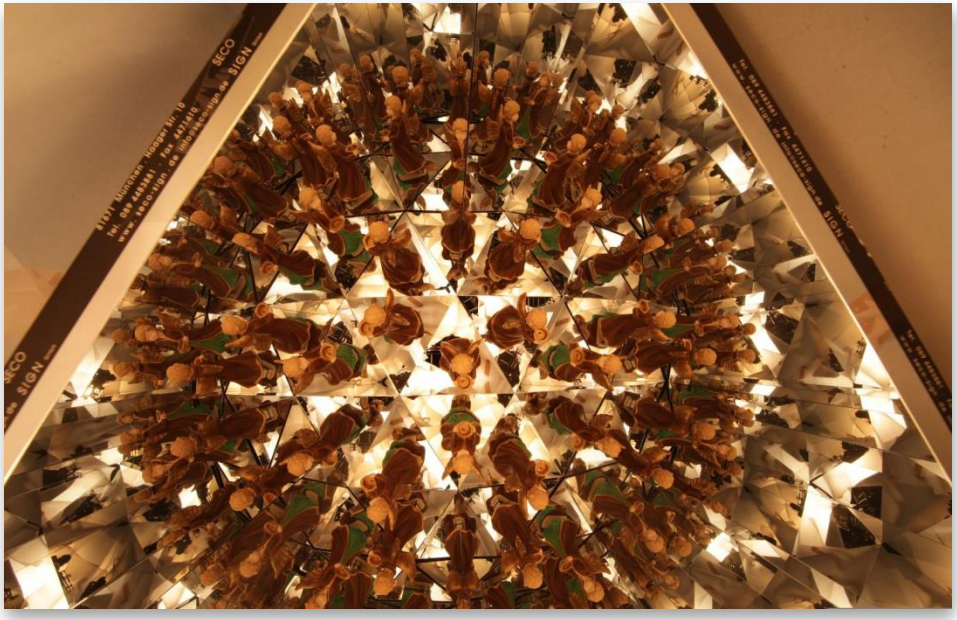


[S. Guthe et al., IEEE Visualization 2002]

Data-Driven Graphics

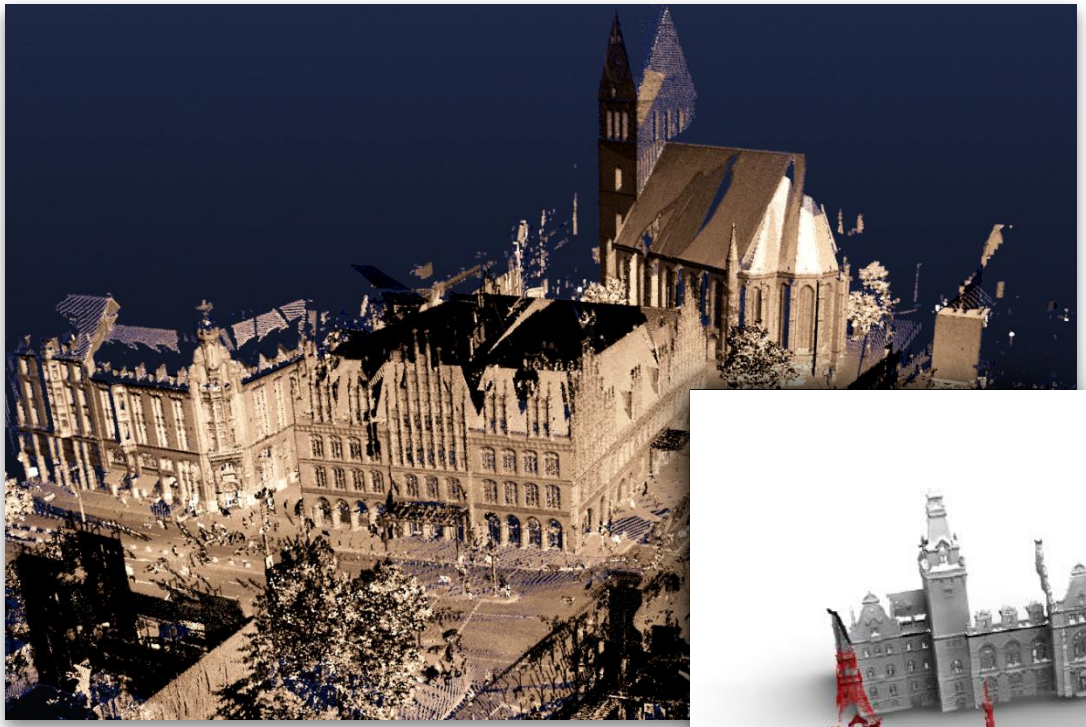
Learning from real-world data

- Complexity of reality
- Machine learning + physical measurement

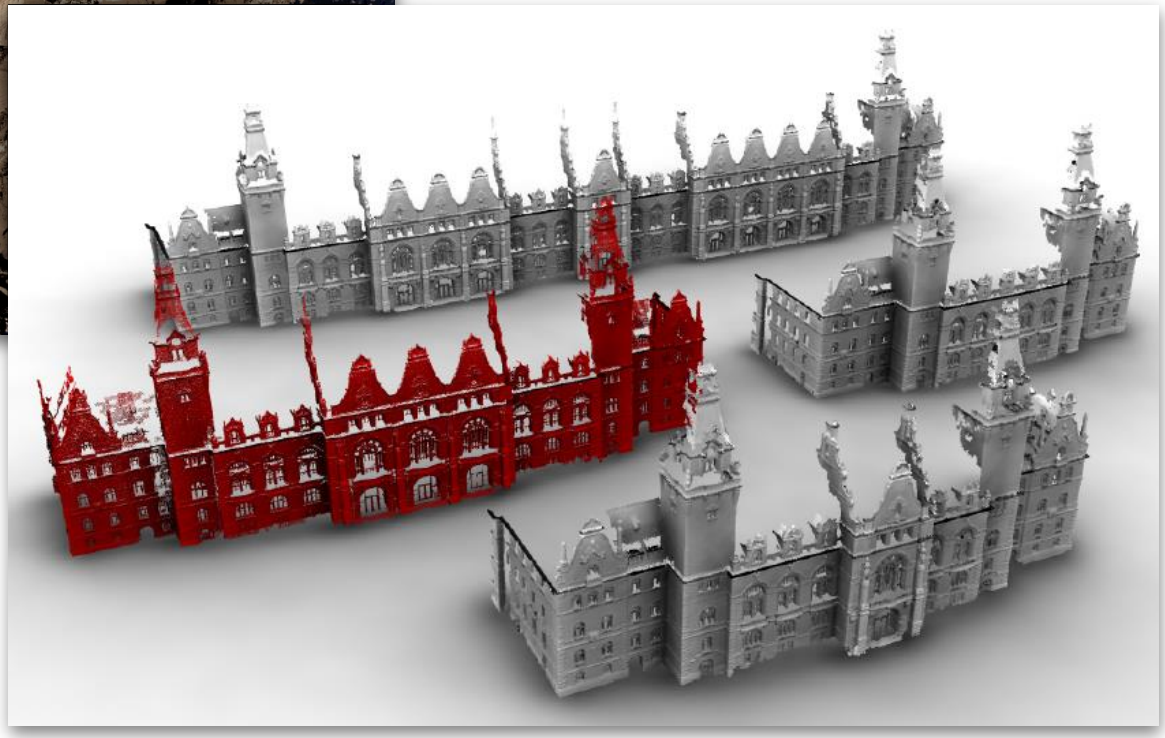


[Ihrke et al., CCD 2012]

Data-Driven Graphics



[courtesy of Claus Brenner, IKG Hannover]



[M. Bokeloh et al., Siggraph 2010]

New Directions

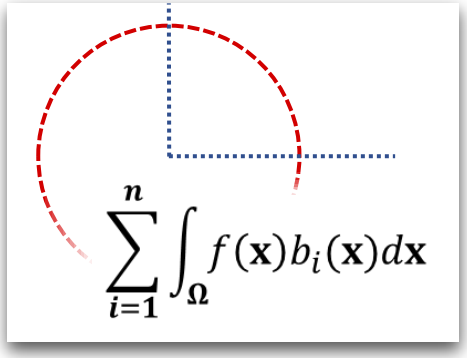
New challenges ahead

- Computational photography
- Fabrication
- Smart image/video editing
- 3D computer vision / scene understanding

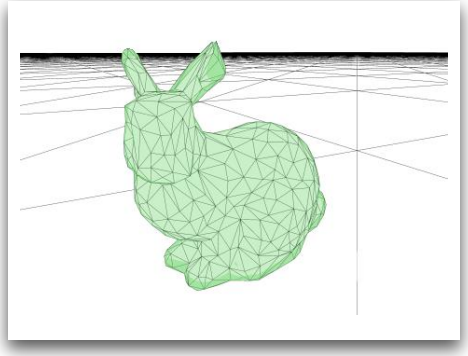
Topics Covered in This Lecture

Topics

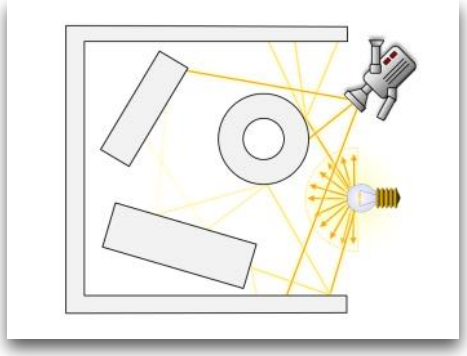
Mathematics ($\approx$ 50%)



Core Graphics ($\approx$ 40%)



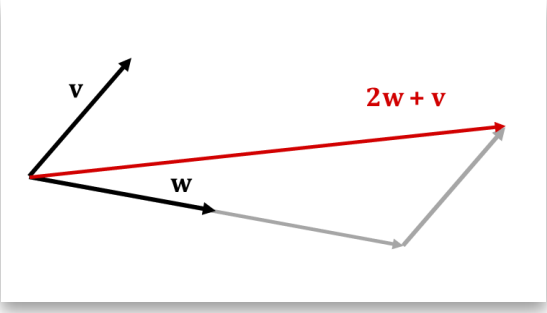
Advanced Graphics ($\approx$ 10%)

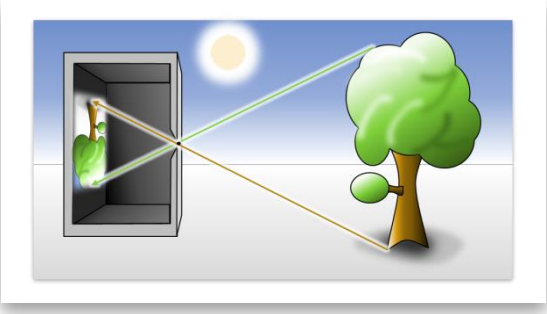


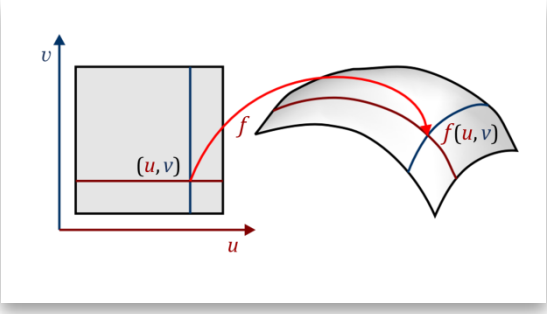
Mathematics

Mathematics

- Linear algebra
  - vectors / points
  - linear maps / matrices
  - linear systems of equations
- Projective geometry
  - Homogeneous coordinates
  - Perspective transformations
- Geometric modeling
  - Primitives (triangles, spheres, etc.)
  - Curves and surfaces
  - Differential properties / normals



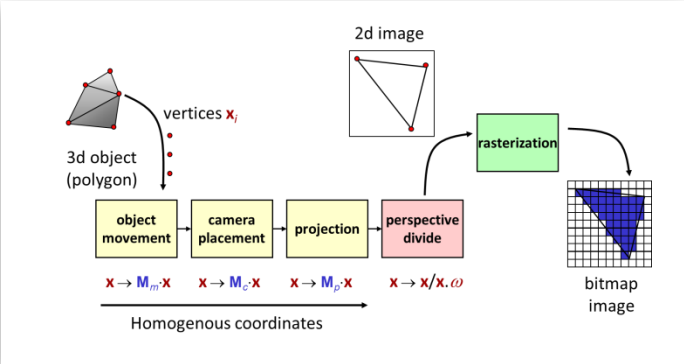


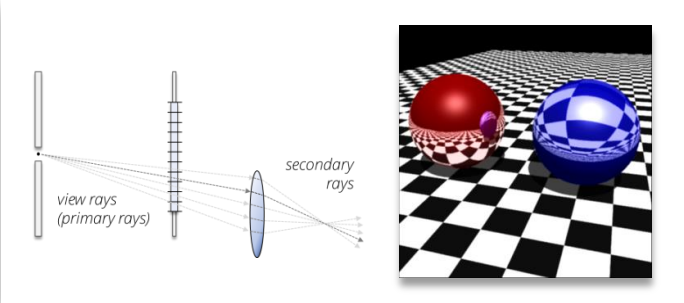


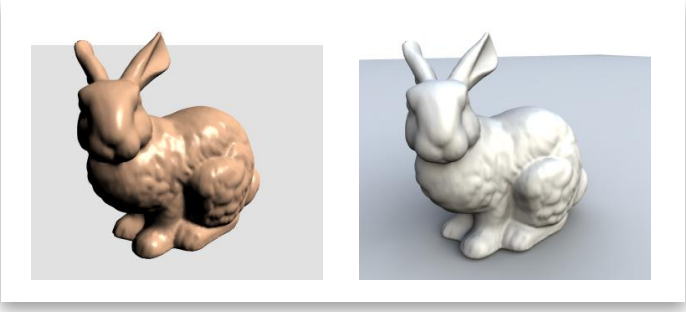
Core Graphics

Core Graphics

- Rasterization
  - Camera models / perspective
  - Visibility algorithms
  - Rasterization pipeline
- Raytracing
  - Ray visibility queries
  - Data structures
  - Recursive raytracing
- Special effects
  - Basic materials
  - Shadows



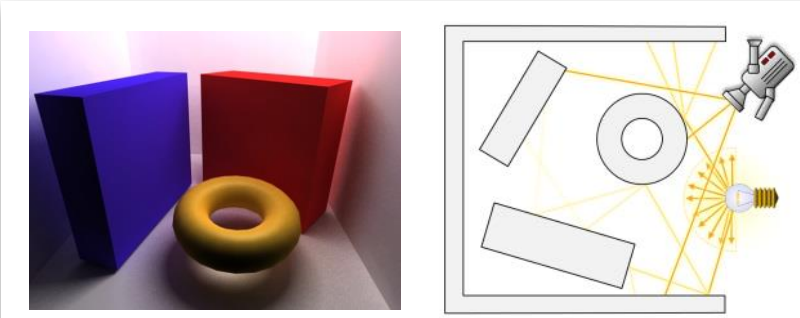




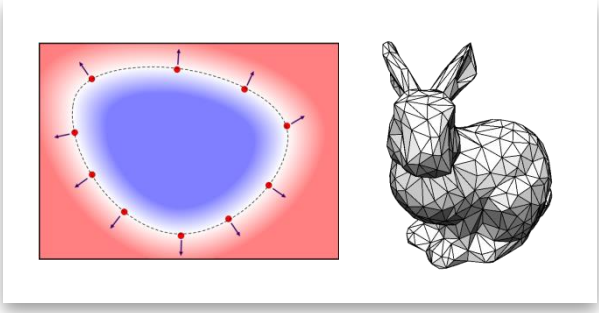
Advanced Graphics

Advanced Topics

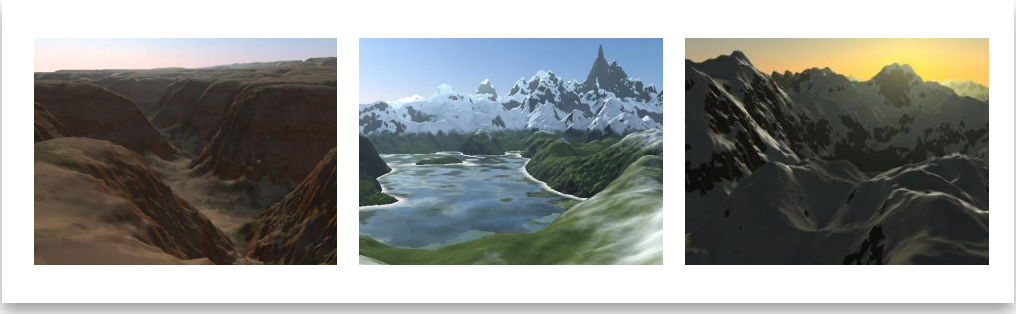
- Global Illumination



- Advanced modeling



- GPUs & Shaders



(as time permits...)

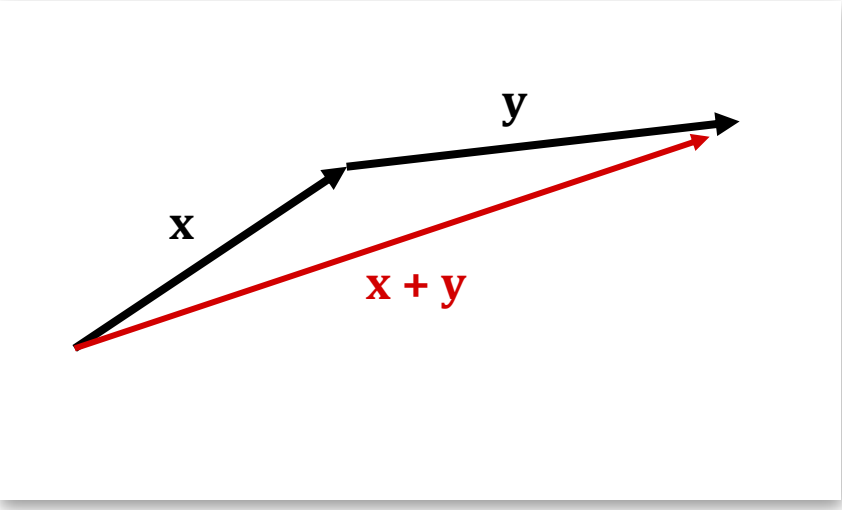
Lecture Fast-Forward

UU Graphics 2014

Step 1: Setting the stage

- We need to describe 2D and 3D geometry
- Language: *Vector spaces*

UU Graphics 2014

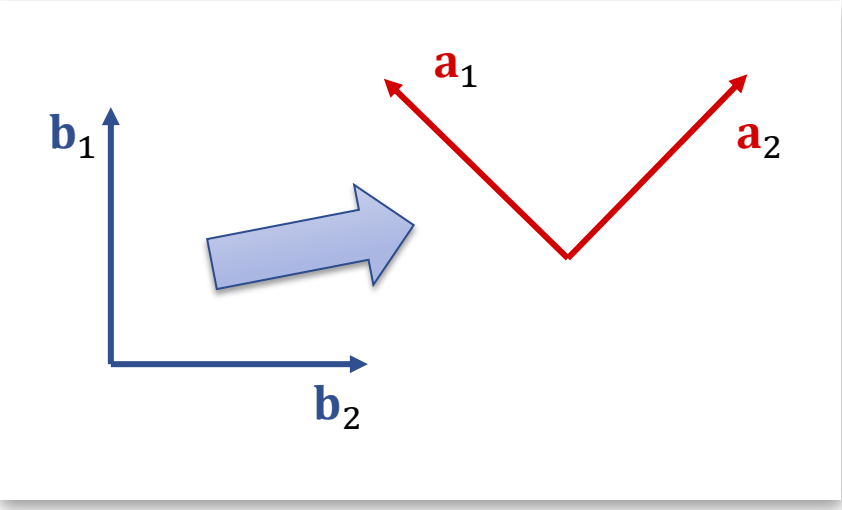


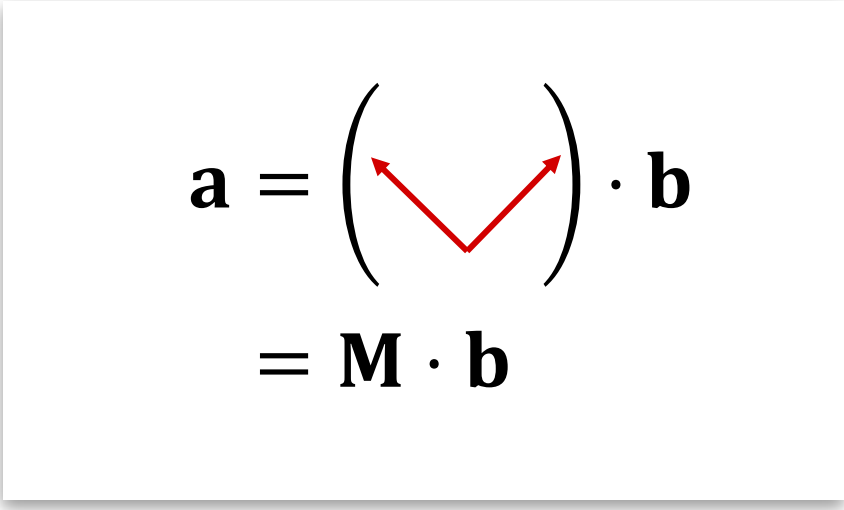
$$\mathbf{x} + \mathbf{y} = \begin{pmatrix} x_1 + y_1 \\ x_2 + y_2 \\ x_3 + y_3 \end{pmatrix}$$

Vectors

- Points / arrows in *d*-dimensional space
- Operation: concatenation (+) and scaling (*)
- Columns of numbers

UU Graphics 2014

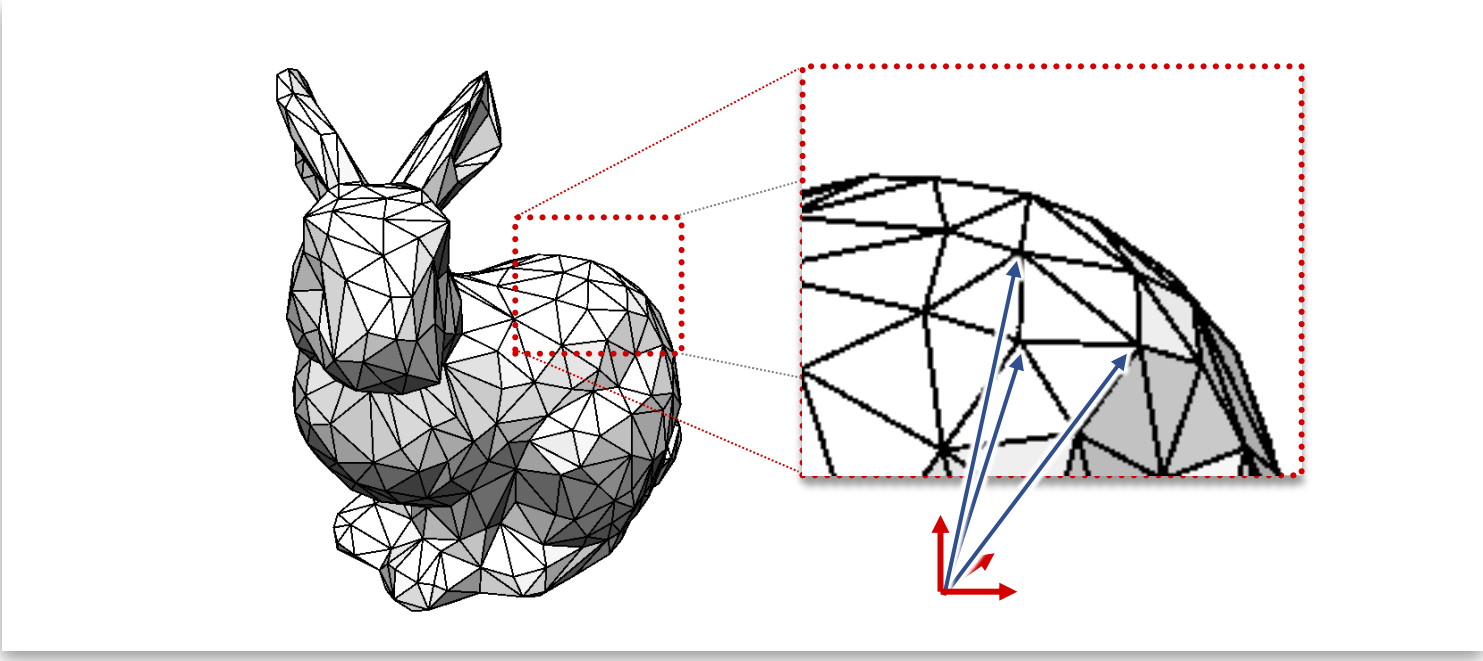




Matrices

- Changing coordinate systems
- Write new coordinates in $d \times d$ array of numbers
- Transformations: scaling, rotation, etc…

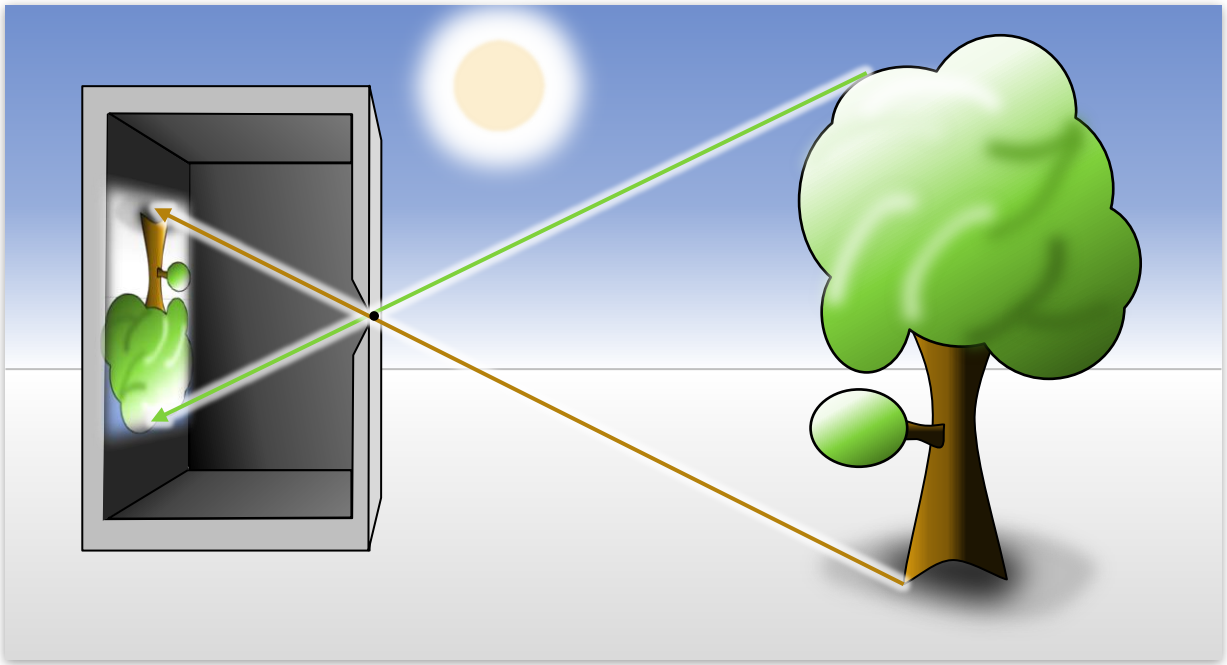
UU Graphics 2014



Modeling

- Primitives: Triangles, spheres, boxes, etc…
- 3 position vectors = 1 triangle
- Transformations

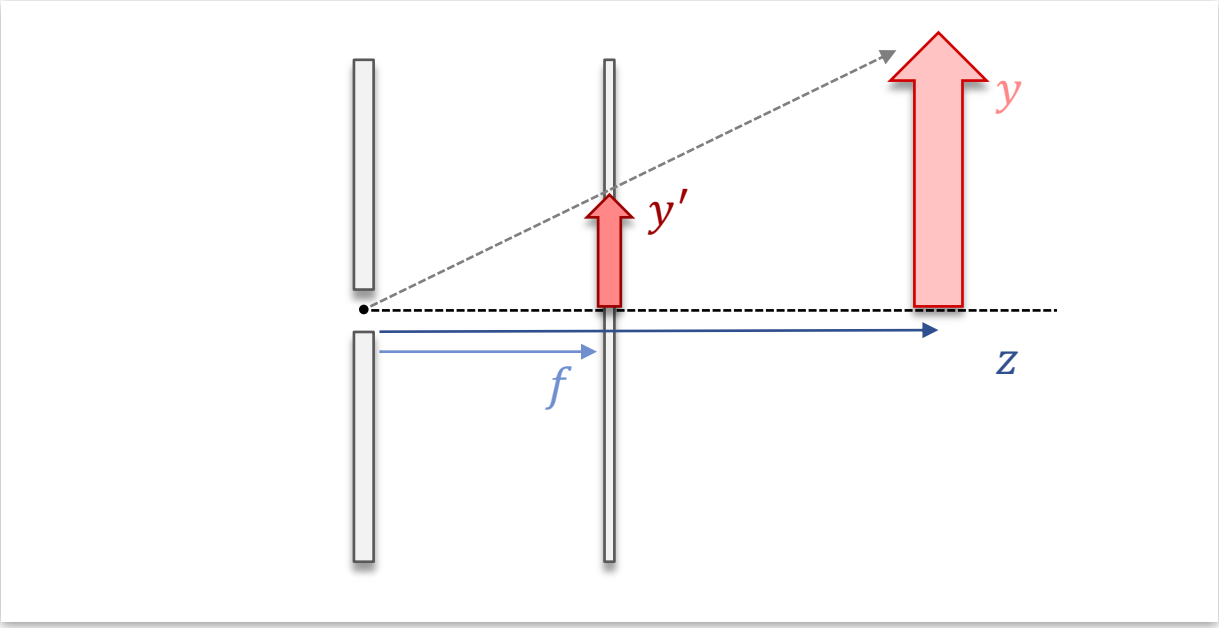
UU Graphics 2014



Perspective projection

- Mapping images to the screen
- Pinhole camera
- Visibility problem

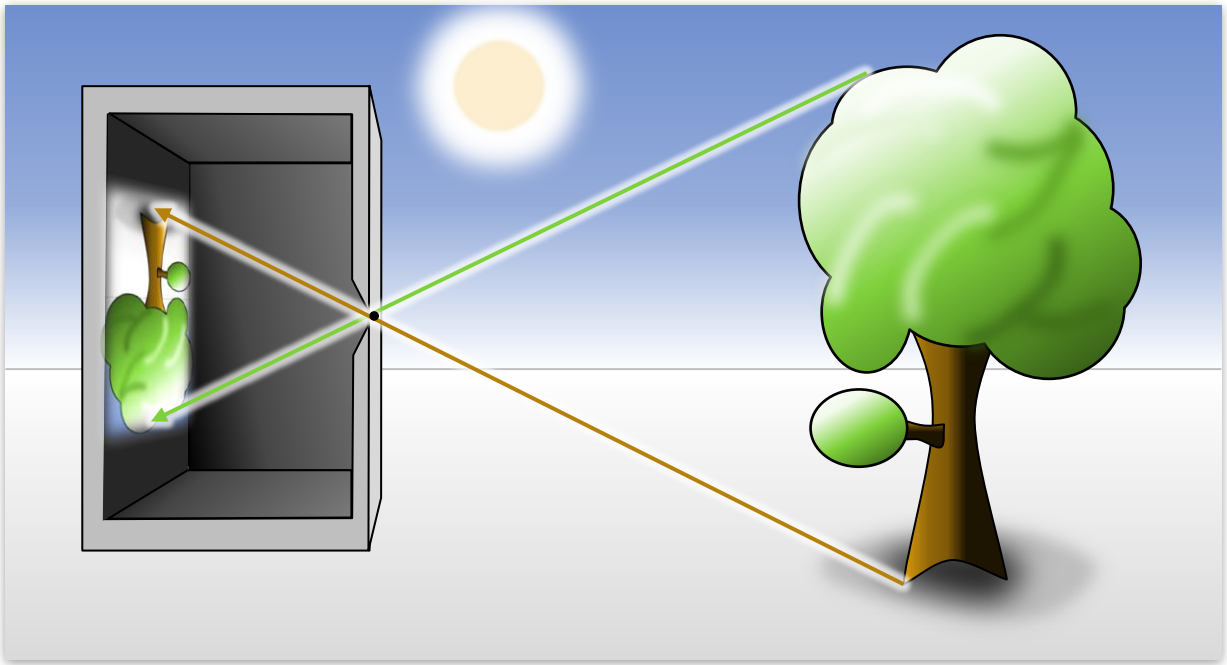
UU Graphics 2014



Mathematics

- Projective geometry
- Homogeneous coordinates

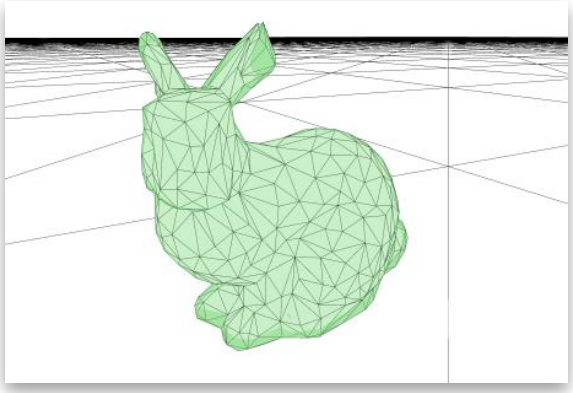
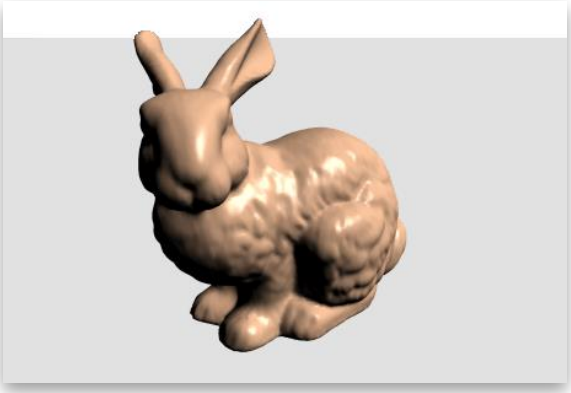
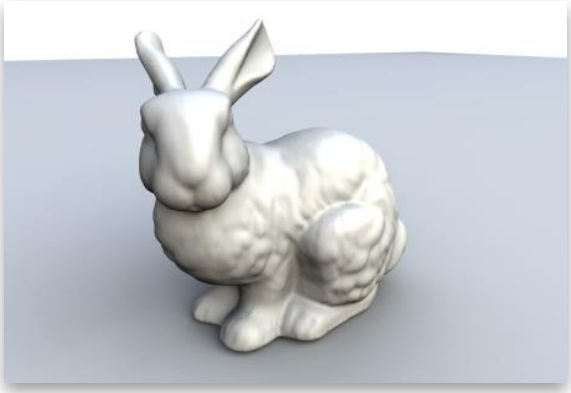
UU Graphics 2014



Computer science

- Visibility algorithms & data structures
- z-Buffer, raytracing

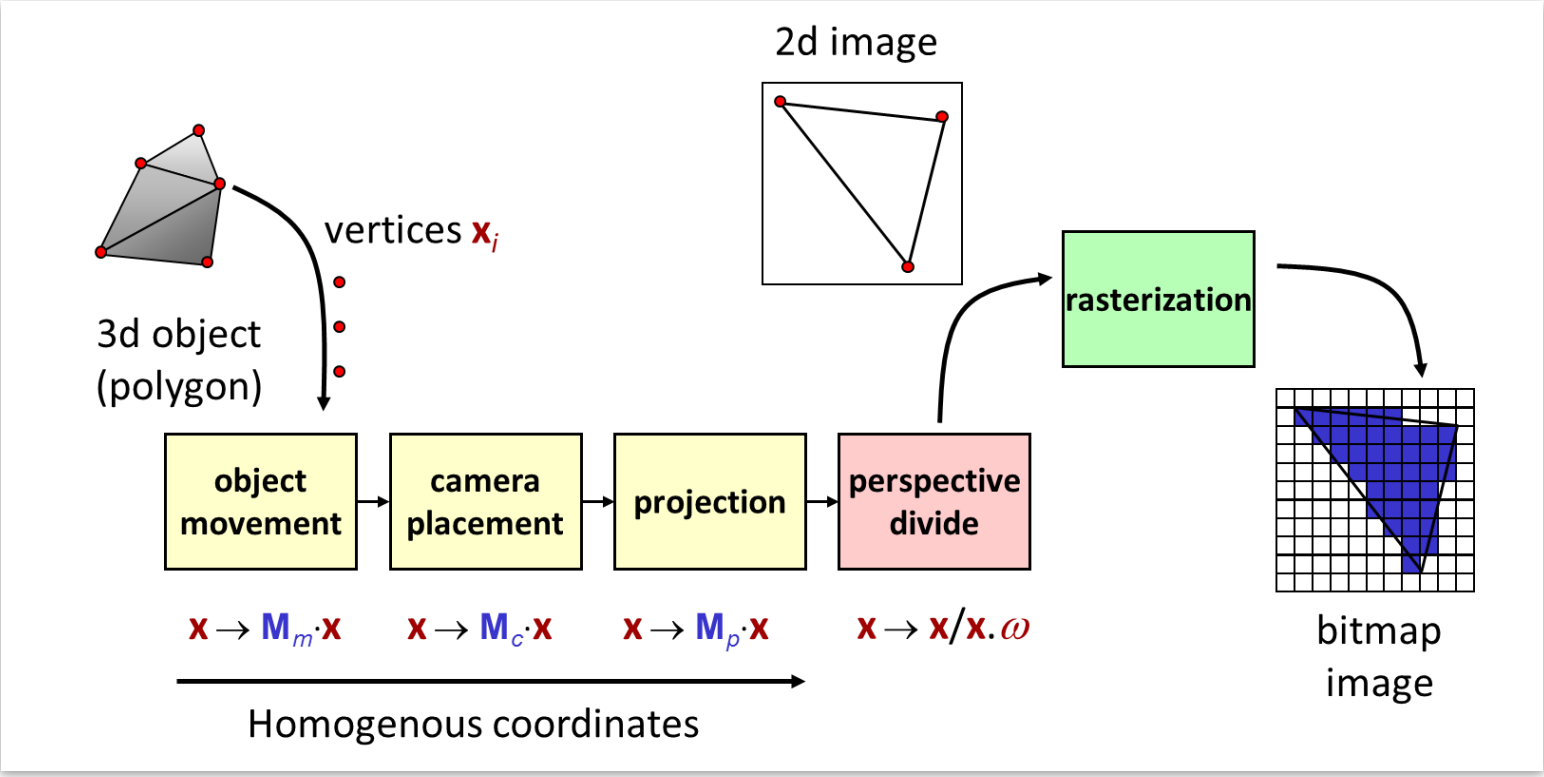
UU Graphics 2014

Shading Models

- Shading models & algorithms
- Normals / surface differentials
- Global effects: Shadows, radiosity, etc…

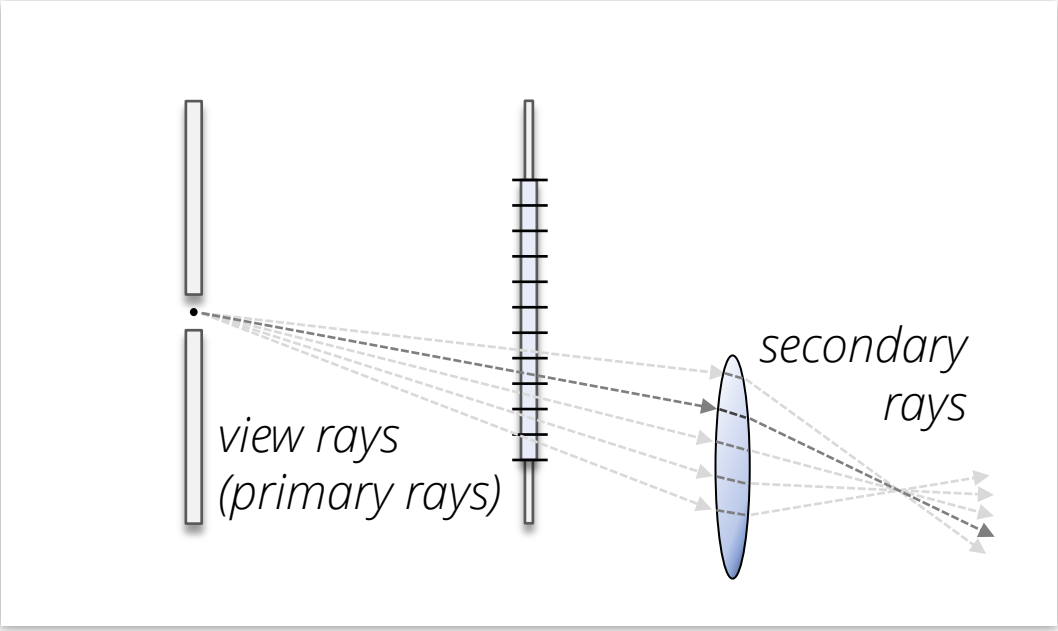
UU Graphics 2014

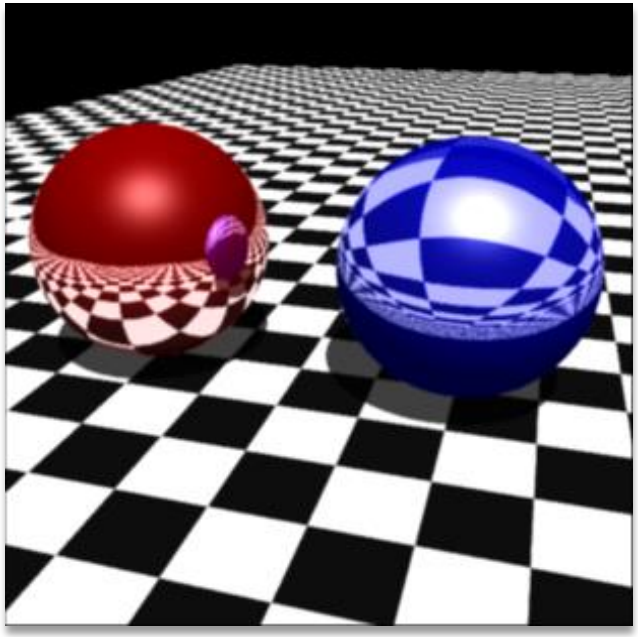


Rasterization Pipeline

- Draw triangles to screen
- Keep closest pixels, apply local shading

UU Graphics 2014

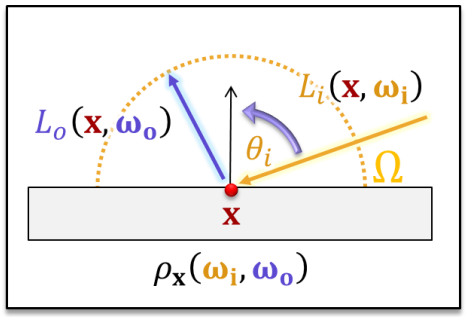


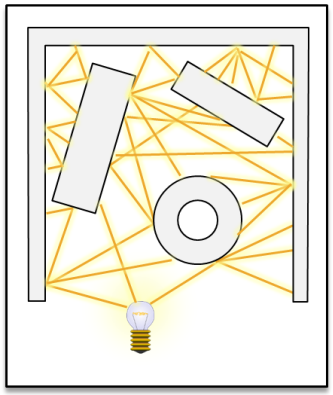


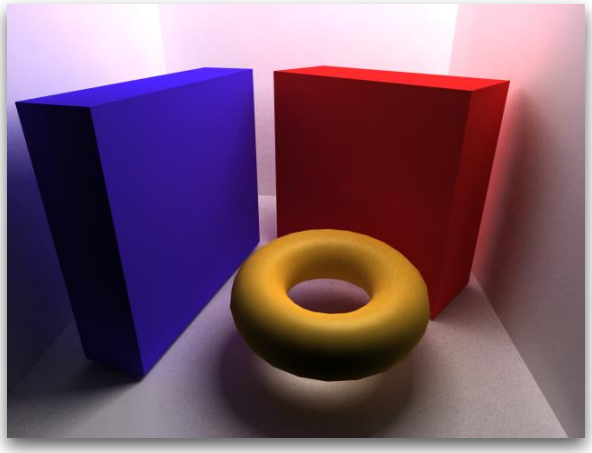
Raytracing Pipeline

- Follow view rays backwards from eye to object
- Includes reflection, transparency, shadows, etc…

UU Graphics 2014







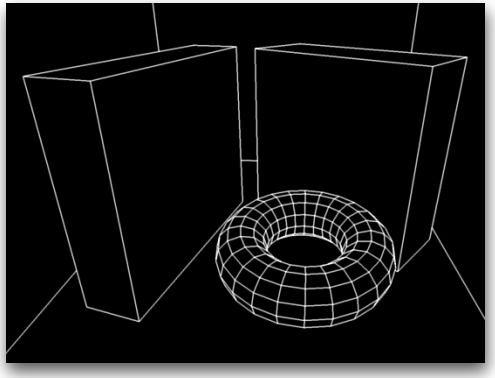
$$L_o(\mathbf{x}, \boldsymbol{\omega}_\mathbf{o}) = \underbrace{E_o(\mathbf{x}, \boldsymbol{\omega}_\mathbf{o})}_{\text{emission}} + \underbrace{\int_{\omega_i \in \Omega} \left[L_i(\mathbf{x}, \boldsymbol{\omega}_\mathbf{i}) \cdot \rho_\mathbf{x}(\boldsymbol{\omega}_\mathbf{i}, \boldsymbol{\omega}_\mathbf{o}) \cdot \cos \theta_\mathbf{i} \right] d\omega_i}_{\text{reflection}}$$

Global Illumination

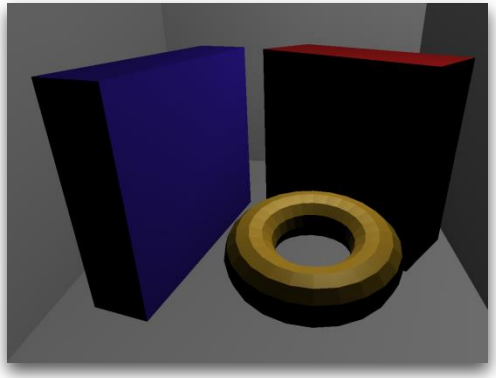
- Radiation Equilibrium:
  Outgoing light = reflected light + emission
- Physically accurate simulation

3D Graphics Summary

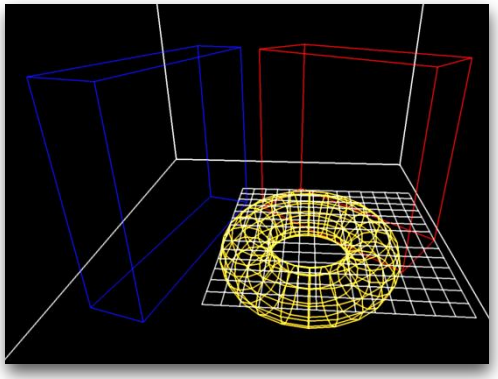
Summary



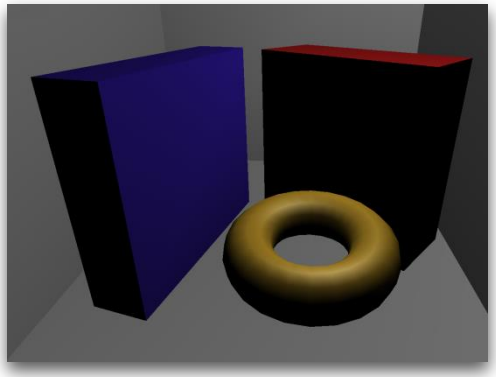
geometric modeling



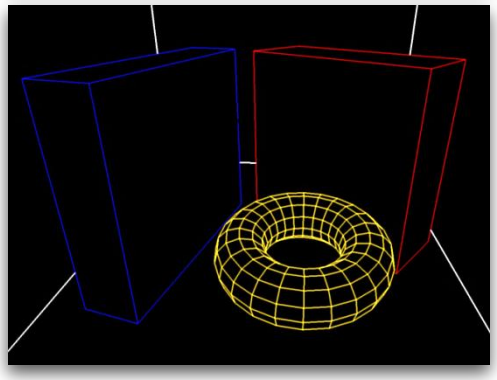
local illumination



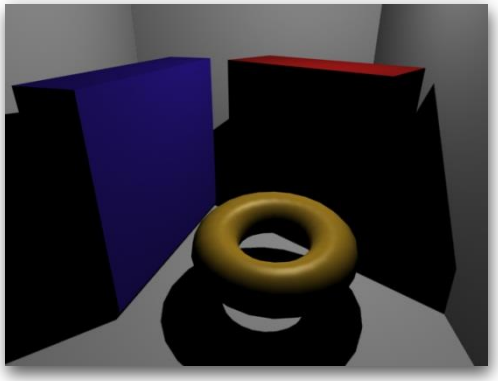
perspective



shading

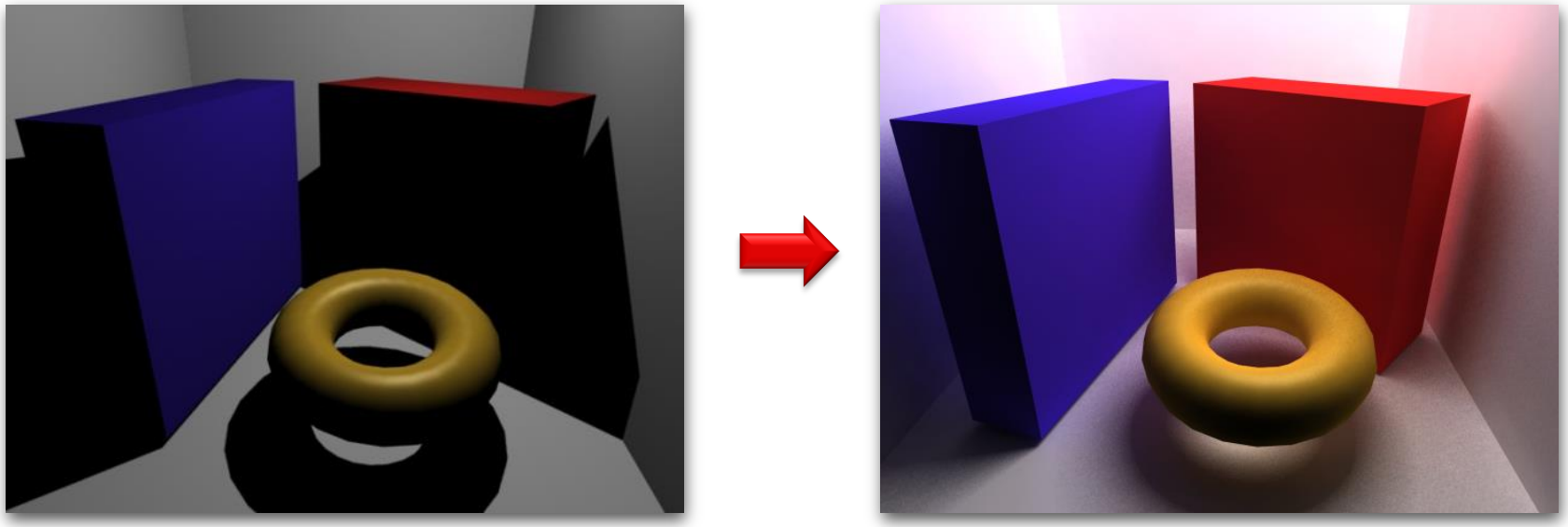


visibility calculation



shadows (global)

Advanced Graphics



Correct global radiance exchange:

- Physical simulation
- We will only take a brief look
- More in master course “Advanced Graphics” (MAGR)