Proseminar
Ausgewählte Themen
der Computergraphik

Matthias Teschner
Outline

- Introduction
- Organization
- Presentation
- Topics
- Summary
Computer Graphics

- **Light**
  - Energy or photons transported along lines
  - Generated by light sources, measured / absorbed by sensors, interacts at surfaces and with participating media

- **Modeling**
  - Geometry, materials, participating media, illumination

- **Rendering**
  - Computation of light transport

- **Simulation**
  - Dynamic rigid bodies, deformable objects and fluids
Computer Graphics

CGI Making of Share a Coke VFX Breakdown by ARMA
MAKING OF
“SHARE A COKE”

Music by: Chocolate Puma & Firebeatz
I Can’t Understand (Original Mix)
Graphics Courses

- Key course
  - Image processing and computer graphics (modeling, rendering, simulation)

- Specialization courses
  - Advanced computer graphics (global illumination)
  - Simulation in computer graphics (deformable and rigid solids, fluids)

- Master project, lab course, Master thesis
  - Simulation track, rendering track
# Seminars / Projects / Theses in Graphics

<table>
<thead>
<tr>
<th>Semester</th>
<th>Simulation Track</th>
<th>Rendering Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>Simulation Course</td>
<td>Key Course</td>
</tr>
<tr>
<td>Summer</td>
<td>Key Course</td>
<td>Lab Course - Simple Ray Tracer</td>
</tr>
<tr>
<td></td>
<td>Lab Course - Simple fluid solver</td>
<td>Rendering Seminar</td>
</tr>
<tr>
<td></td>
<td>Simulation Seminar</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>Master Project - PPE fluid solver</td>
<td>Rendering Course</td>
</tr>
<tr>
<td></td>
<td>Rendering Seminar</td>
<td>Master Project - Monte Carlo RT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simulation Seminar</td>
</tr>
<tr>
<td>Summer</td>
<td>Master Thesis</td>
<td>Master Thesis</td>
</tr>
<tr>
<td></td>
<td>Research-oriented topic</td>
<td>Research-oriented topic</td>
</tr>
</tbody>
</table>
Outline

- Introduction
- Organization
- Presentation
- Topics
- Summary
Requirements

– Oral presentation of a graphics topic
– Written report
Presentations

– Three meetings with three presentations per meeting towards the end of the semester
– Take place at the same time and in the same room as the introduction or per video conference
  – Announced in the course catalog and on our web page https://cg.informatik.uni-freiburg.de/teaching.htm
– Attendance is mandatory
– No other regular meetings
Report and Submissions

– Written report (approx. 10 pages)
– Submission of presentation slides and written report in two separate PDF files
  – YourLastName_report.pdf
  – YourLastName_presentation.pdf
– Per email to Prof. Teschner
– Until the last day of lectures of the semester
Consultations

- Two voluntary consultations
- Requested per email
- First consultation
  - General discussion of the outline
  - Content questions
- Second consultation
  - Discussion of the fully prepared presentation
  - Not later than one week prior the presentation
Information

- https://cg.informatik.uni-freiburg.de/
  - Teaching
    - Ausgewählte Themen der Computergraphik
    - Termine / Themen
Outline

– Introduction
– Organization
– Presentation
– Topics
– Summary
Presentation

- 20 min – 25 min per presentation
- 5 min – 10 min discussion
  - Technical questions
  - Form of the presentation
Preparation

– Know your topic
  – Examine relevant material thoroughly
  – Do not try to circumvent problems

– Prepare slides
  – Allow 1 to 2 minutes per slide
  – Slides should be uniform and not too dense
  – Incorporate illustrations, slide titles should be helpful

– Rehearse your presentation
  – Gather feedback, adapt your presentation accordingly
Presentation

– Introduction
  – Introduce yourself and the title of your presentation

– Overview
  – Give an idea, but not too detailed

– Motivation
  – Illustrate the principle and / or applications
  – Explain the goal of your presentation
  – The audience should be eager to listen your presentation
Presentation

- Main part
  - Should consist of distinguished parts
  - Separate different parts of the presentation explicitly
  - Each part should be introduced and summarized

- Summary
  - Tell the audience what you have told them
  - Ask for questions
Presentation

– Check the presentation environment prior to the presentation
– Do not occlude the projection
– Avoid idiosyncrasies
– Stay in time
Outline

– Introduction
– Organization
– Presentation
– Topics
– Summary
Information

– https://cg.informatik.uni-freiburg.de/
  – Teaching
    – Ausgewählte Themen der Computergraphik
    – Themen
Homogeneous coordinates

Die homogene Notation ist eine in der Graphik häufig verwendete Repräsentation von Positionen und Richtungen, die eine einheitliche Realisierung vielfältiger Transformationen von Positionen und Richtungen durch ein einfaches Matrix-Vektor-Produkt ermöglicht.

Quellen:
- https://cg.informatik.uni-freiburg.de/course_notes/graphics_03_homogeneousNotation.pdf
Topics

– Rendering
  Rendering pipeline, Bresenham algorithm, Ray tracing, Phong illumination model, William shadow mapping

– Modeling
  Marching Cubes, Mesh simplification

– Animation
  Particle systems

– Tools
  Homogeneous coordinates
Modeling and Rendering

© Will Gibbons Design
Ray Tracing

– Computation of light transport along rays
Phong Illumination Model

- Computes reflected light at surfaces considering illumination and material

Incoming light is scattered and absorbed at surfaces dependent on the material.
Phong Illumination Model

- Computes reflected light at surfaces considering illumination and material

\[ L(p, l_1) \quad L(p, l_2) \]

\[ \begin{align*}
L(p, v) &= \sum_i f_{\text{Phong}} \left( L(p, l_i) \right) \\
\end{align*} \]

\( f_{\text{Phong}} \) computes reflected light into direction \( v \) towards the sensor considering illumination from directions \( l_i \).
Ray Tracing vs. Rasterization

– Solve the visibility problem

Ray Tracers compute ray-scene intersections to estimate $q$ from $p$.

Rasterizers apply transformations to $p$ in order to estimate $q$. $p$ is projected onto the sensor plane.
Rendering Pipeline

\[ PV^{-1}M_i \]

Object in local space

Scene in the canonical view volume

Rasterization

Visibility

Shading (e.g. Phong)

Image
Transformations

Four faces / primitives / polygons, four points / vertices, four normals

Translation

Scale

Identity transform

Rotation

Shear

Transformations change vertex positions and surface normals.
Homogeneous Notation

- All transformations of positions and directions are uniformly realized as a matrix-vector product.

- Translation of a point \( \mathbf{p} = (p_x, p_y, p_z)^T \)
  and a vector \( \mathbf{v} = (v_x, v_y, v_z)^T \) by a vector \( \mathbf{t} = (t_x, t_y, t_z)^T \)

\[
\begin{bmatrix}
1 & 0 & 0 & t_x \\
0 & 1 & 0 & t_y \\
0 & 0 & 1 & t_z \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
p_x \\
p_y \\
p_z \\
1
\end{bmatrix}
= 
\begin{bmatrix}
p_x + t_x \\
p_y + t_y \\
p_z + t_z \\
1
\end{bmatrix}
= 
\begin{bmatrix}
1 & 0 & 0 & t_x \\
0 & 1 & 0 & t_y \\
0 & 0 & 1 & t_z \\
0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
v_x \\
v_y \\
v_z \\
0
\end{bmatrix}
= 
\begin{bmatrix}
v_x \\
v_y \\
v_z \\
0
\end{bmatrix}
\]

Translation of a point in homogeneous notation
Translation of a vector in homogeneous notation
Bresenham Algorithm

- Estimation of pixel positions that approximately represent a line from $p_b = (x_b, y_b)$ to $p_e = (x_e, y_e)$
Shadow Mapping

- Camera
- Light
- Image plane

A
B
C
Marching Cubes

– Reconstruction and rendering of a triangulated iso-surface

Akinci et al.: Versatile Rigid-Fluid Coupling for Incompressible SPH
Marching Cubes

Input: Scalar field

Classification with respect to an iso-value, e.g. 8

Output: Triangulated iso-surface
Mesh Simplification

577 k triangles

Botsch et al.: Polygon Mesh Processing

10 %

1 %

0.1 %
Particle Systems

- Particle representation
- Force computation
- Particle motion

\[ \frac{F}{m} = \frac{dv}{dt} = \frac{d^2 x}{dt^2} \]

Object  Particles  Acceleration  Velocity change  Position change

University of Freiburg – Computer Science Department – 39
Outline

- Introduction
- Organization
- Presentation
- Topics
- Summary
Summary

- Two voluntary consultations
- Oral presentation of 20 – 25 min
- Written report of 10 pages
- Topics overview and presentation dates
  - https://cg.informatik.uni-freiburg.de/teaching.htm
    - Ausgewählte Themen der Computergraphik
    - Termine / Themen