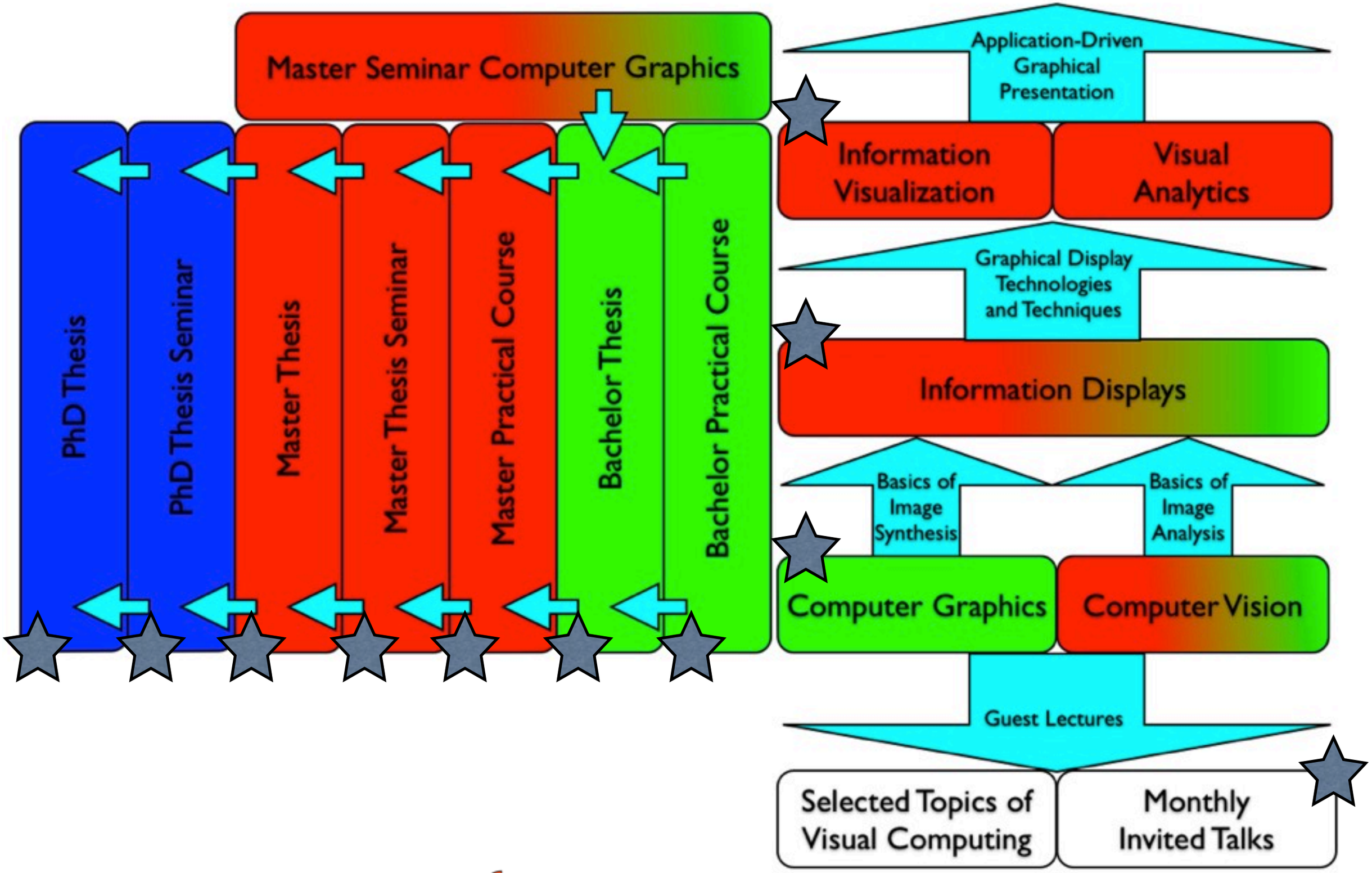
Computer Graphics

-Introduction and Course Overview-

Oliver Bimber

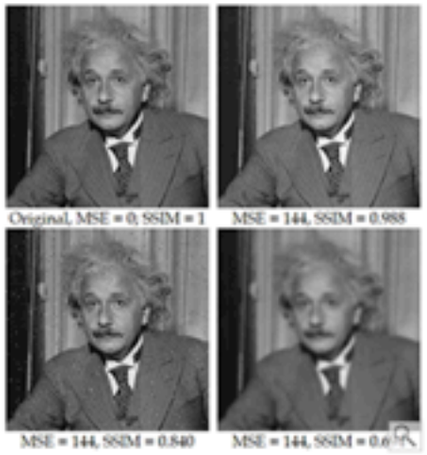
What We Teach and Research



Available Student Projects

Structured Similarity Index for Light Fields

Topics: light fields, quality metric, SSIM, processing, Matlab
Supervision: David Schedl, Oliver Bimber
Contact: david.schedl@jku.at
Type: BSc Thesis, (MSc Thesis)



The Structured Similarity (SSIM) index is the de facto standard quality metric for the perceptual comparisons of a modified image with its ground truth. While the mean squared error (MSE) produces similar scores for differently degraded images (see image), the SSIM generates scores that are in correlation with a human viewer. Although SSIM has been extended to other domains (e.g., video), no extension for light fields is available. The SSIM cannot be directly applied to light fields, because multiple views require additional considerations. The goal of this project is to develop a first light-field SSIM.
Initial experiments/ideas for a light-field SSIM have already been carried out previously by students and can be used as a starting point for the project.

Additionally, master students should conduct a user study, on human light-field perception, which is used for evaluating and tuning the metric (see Project: User Study on Light-Field Perception).

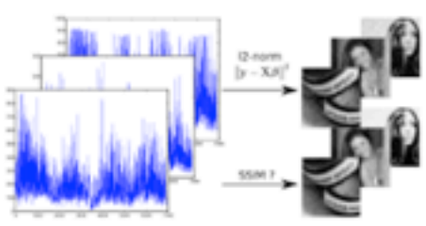
User Study on Light-Field Perception

Topics: light fields, quality metric, processing, user study, online
Supervision: David Schedl, Oliver Bimber
Contact: david.schedl@jku.at
Type: BSc Thesis

For images human-rated image databases exist (e.g., TID2008 database). Such databases contain several images and differently degraded versions of each image. For each pair (original vs. modified image) a quality score from a user study is available. Such databases are used for the assessment and tuning of perceptual image quality metrics, such as Structured Similarity (SSIM). For light-fields, however, no such database is available.
The goal of this project is to establish a representative light-field database with degraded light fields and to conduct a user study on human light-field perception. The database and the results of the study are of interest for researchers that develop new light-field quality assessment techniques. Therefore, the results will be published in an international journal or at an international conference. On acceptance the student will be sent to a conference by our institute.
Preliminary work/research for this project has already been carried out: A modified version of the Stanford Viewer for viewing two light fields in parallel is already available. Plugins for rendering virtual light fields with Blender are usable. Furthermore, databases with freely available light fields exist.

Improved image reconstruction using perceptually-motivated objective functions

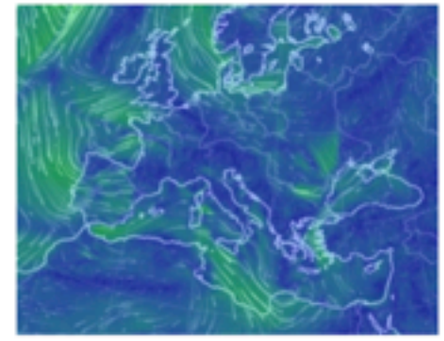
Topics: machine learning, signal processing, Matlab
Supervision: Alexander Koppelhuber, Oliver Bimber
Contact: alexander.koppelhuber@jku.at
Type: BSc Thesis, MSc Thesis, MSc Practicum, BSc Practicum



Our current image reconstruction approach for our thin-film luminescent concentrator image sensor is to use Ordinary Least Squares to estimate the inverse light transport matrix. This allows a simple matrix-vector multiplication to reconstruct the image from the measured signal. This research project aims to increase the reconstruction quality by investigating the use of a different objective function than the l2-norm which is known to correlate poorly with the perceived image quality. In a recent paper ([1]) the structural similarity index (SSIM) was used to improve the image quality in the context of demosaicing and denoising. Is it possible to use SSIM (or other metrics) as the objective function for image reconstruction from projections?
[1] "Is L2 a Good Loss Function for Neural Networks for Image Processing?".

Airplane Heading Correction with Wind Prediction

Topics: airplane navigation, weather databases, Android, Java
Supervision: Clemens Birklbauer, Oliver Bimber
Contact: clemens.birklbauer@jku.at
Type: BSc Practicum, BSc Thesis, MSc Practicum



Airplanes are heavily influenced by the wind during navigation. For steering in a certain direction the wind has to be compensated. This means the actual heading of a plane in the air is different to its moving direction over ground provided by GPS tracking. This is a problem e.g. for augmented reality systems that rely on GPS based heading information.
With known wind speed and direction the actual heading of the airplane can be computed. Existing applications rely on manual user inputs to compute the required wind parameters which have to be updated frequently.
The goal of this project is to replace the manual wind compensation with automatically computed values from weather forecast systems (e.g. GFS, ICON) looked up for the current GPS position and height. Data should be downloaded and preprocessed before flights (for a desired region). In a first step freely available weather databases should be explored. Furthermore an Android app has to be implemented that downloads wind values and supports a comparison with a manual wind computation during flight. Exact GPS data is provided by an iLevil device.

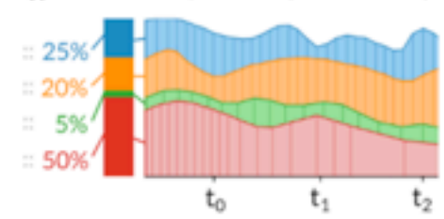
Fusing Data Analysis with Data Wrangling

Topics: visualization, visual analytics, big data, D3.js, Python
Supervision: Samuel Gratzl, Marc Streit
Contact: samuel.gratzl@jku.at
Type: BSc Practicum, BSc Thesis, MSc Practicum, MSc Thesis

Solving data intensive problems requires users to merge and analyze datasets that come from different sources, in various formats and semantics. The current workflow in visual data analysis is to first import and specify the semantics of the datasets in a standard importer dialog, before moving on to the actual visual analysis. However, when dealing with multiple, heterogeneous datasets the back and forth between data import and analysis results in a disruption of the workflow that hampers the sense making process. The goal of this project is to seamlessly fuse the data import with the data analysis. The project will be implemented in the Caleydo Web framework, which is based on D3.js, JavaScript and Python.

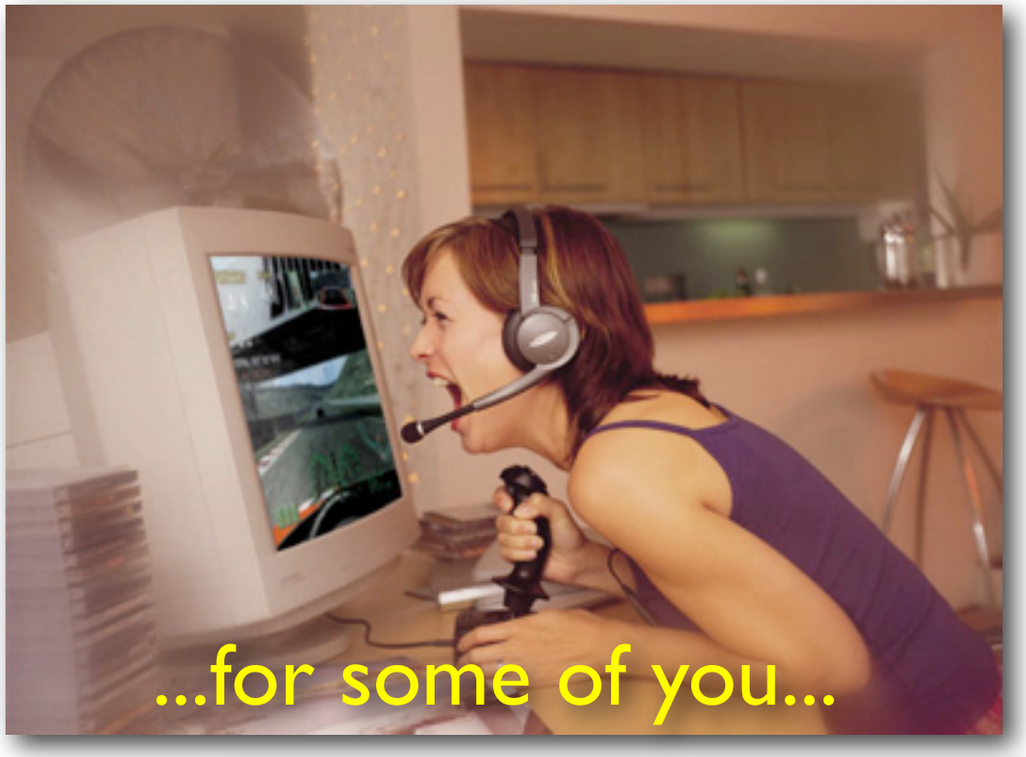
Visualizing Degree-of-Interest Functions over Time

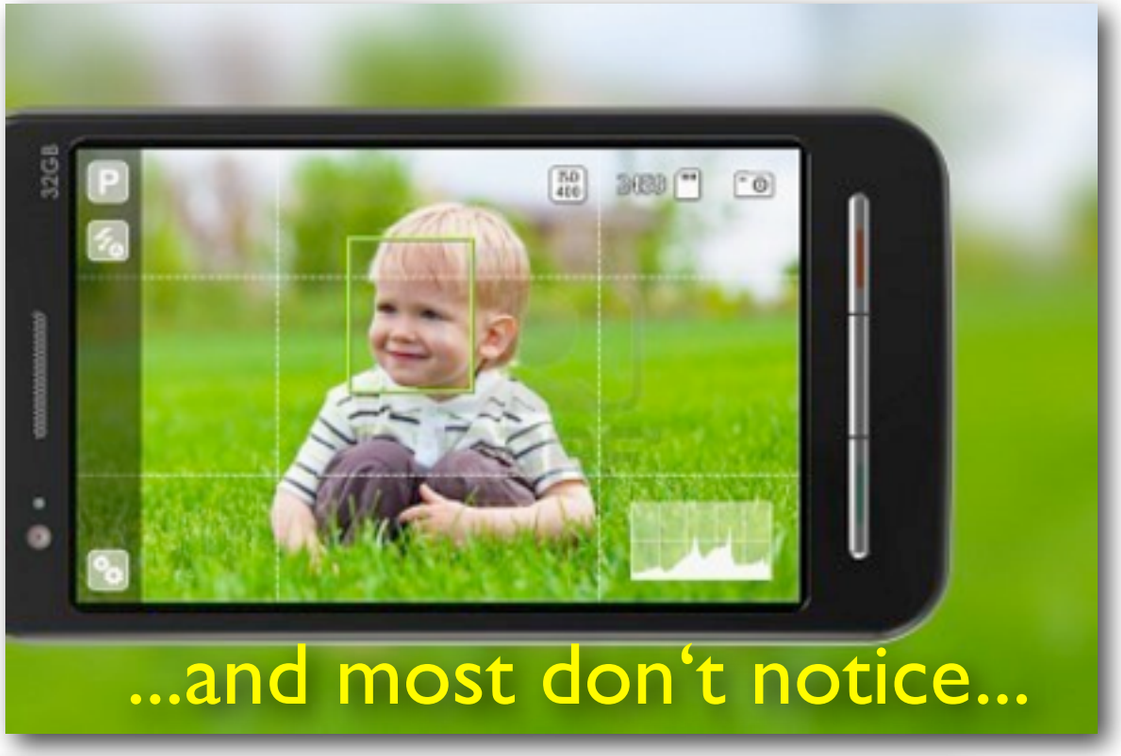
Topics: visualization, big data, guidance, D3.js
Supervision: Holger Stitz, Marc Streit
Contact: holger.stitz@jku.at
Type: BSc Practicum, BSc Thesis, MSc Practicum, MSc Thesis



Multi-attribute time-series data plays an essential role in many different domains, such as economics, sensor networks, and biology. An important task when making sense of such data is to provide users with an overview to identify items that show an interesting development over time. In earlier work, we presented ThermalPlot, a visualization technique that summarizes combinations of multiple attributes over time. Techniques such as ThermalPlot are based on a user-defined Degree-of-Interest (DoI) function that is a weighted combination of multiple attributes. However, such complex DoI functions and their effects on the visualization are hard to comprehend by users.
The goal of the project is to effectively visualize weighted multi-attribute DoI functions. The solution should go beyond standard stacked stream graphs and should consider dynamic weights, missing values, and different levels of granularity. The project will be implemented as independent library that should later on be used in the Caleydo Web framework.

What is Computer Graphics?





What is Computer Graphics?

Graphics or Photo?

graphics

photo (this is a robot)

Graphics or Photo?

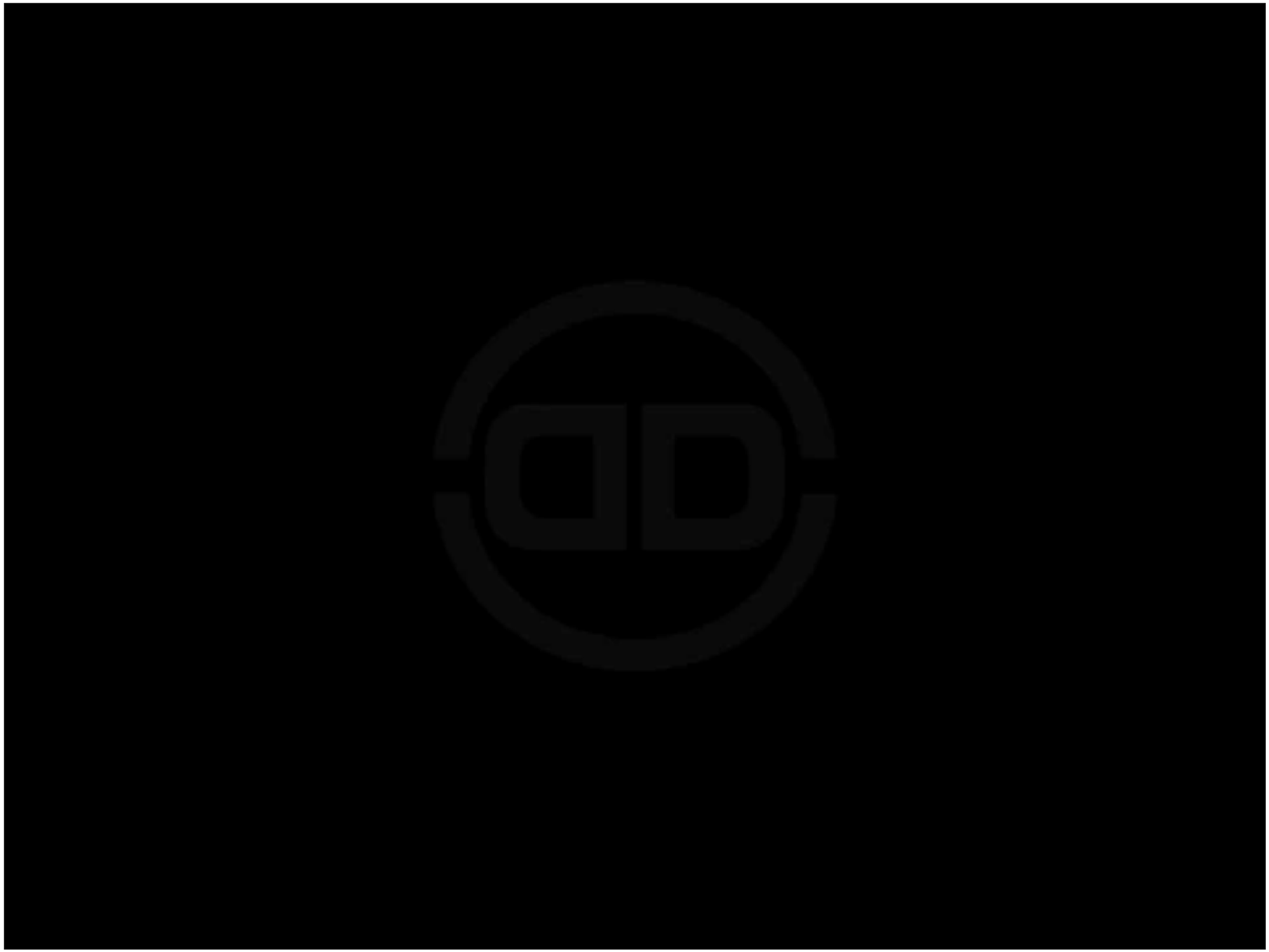
both graphics

Graphics or Video?

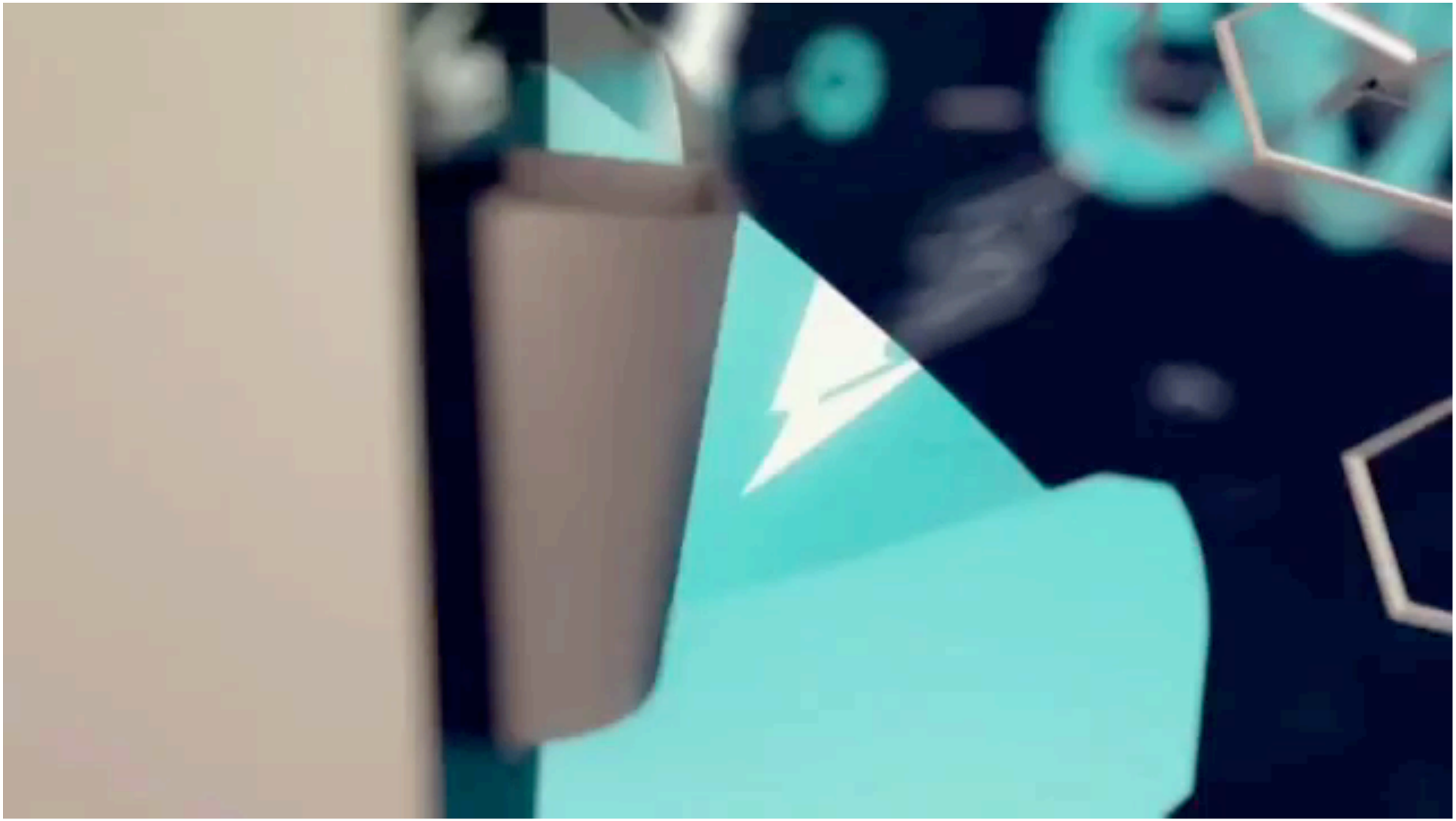
Graphics or Video?

well...

Graphics or Video?



Graphics done Wrong!



What this Course is About

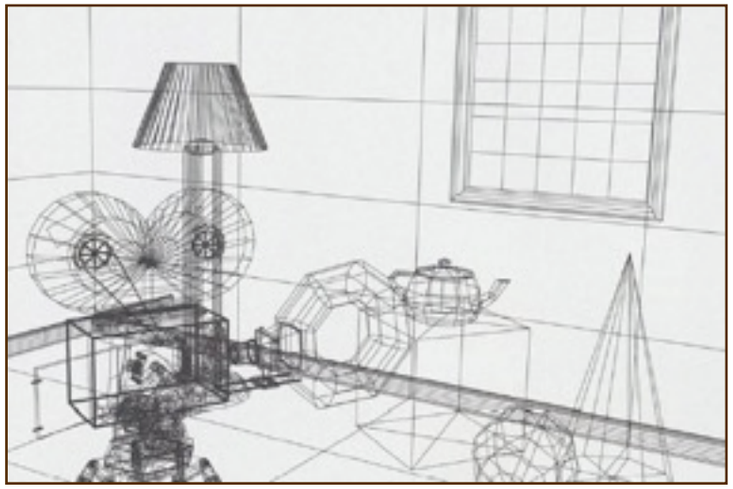
- Computer graphics methods are essential for many areas, such as visual effects in movies, computer games, scientific and information visualization, and many others
- You experience computer graphics every day (yet, you might not always be aware of it)
- In this course, you will learn basic computer graphics techniques, and you will understand the general concepts behind real-time and photo-realistic rendering
- Besides the fundamental principles, this course will also provide a glance on modern approaches in computer graphics
- A sufficient introduction into WebGL, GPU shader programming and visualization libraries, such as VTK are parts of the hands-on component of this class

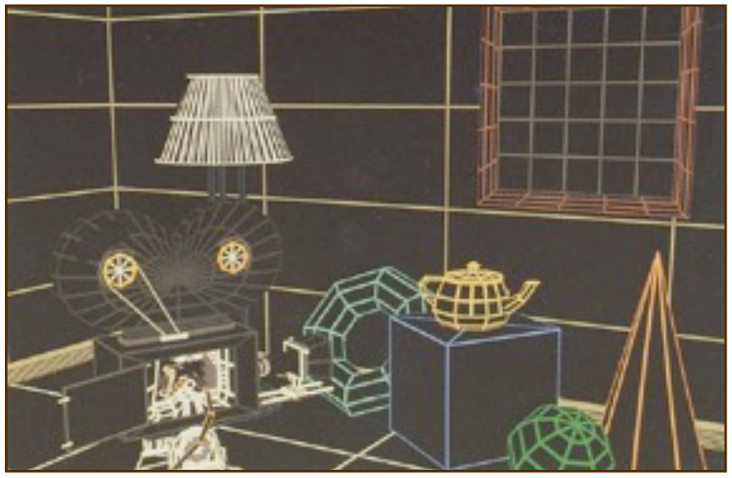
Computer Graphics: The First 30 Years

- William Fetter of Boing coined the term in 1960...
- ...but with Ivan Sutherland's Sketchpad System, the era of interactive computer graphics began in 1963
- Vector displays were used first, such as modified oscilloscopes in 1963, or Evans and Sutherland Picture System in 1974
- The first raster displays were supported by Evans and Sutherland frame buffers in 1975
- Frame buffer became really cheap in the '80s, which enabled the first bit-mapped personal computers

Computer Graphics: The First 30 Years

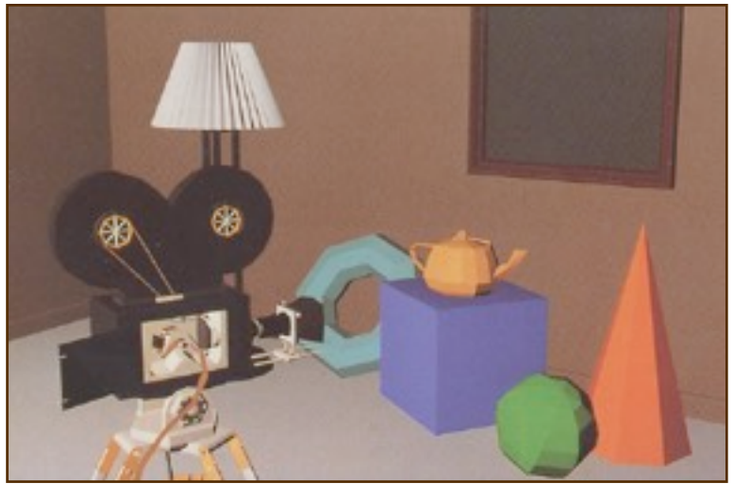
- From a 3D rendering point of view, the visibility problem was solved in the '60s and '70s
  - Roberts (1963), Appel (1967): hidden-line algorithms
  - Warnock (1969), Watkins (1970): hidden-surface algorithms
  - Sutherland (1974): visibility sorting





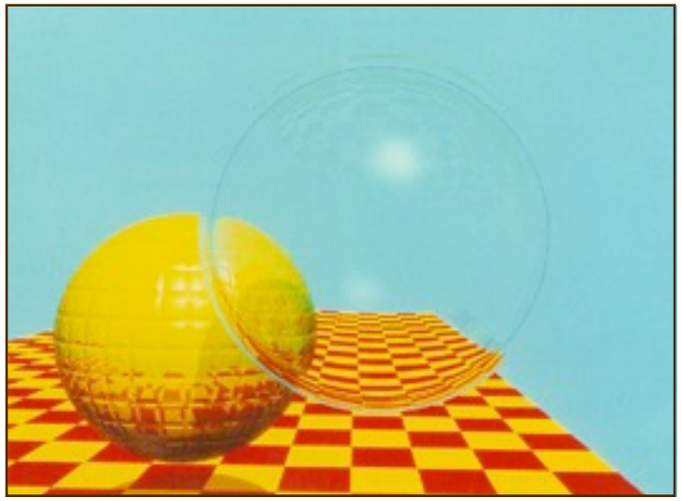
Computer Graphics: The First 30 Years

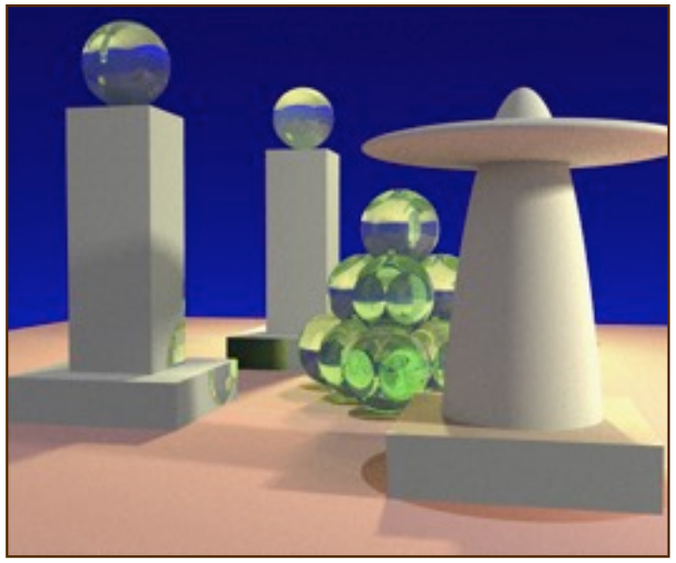
- The first rastering and shading algorithm were developed in the '70s
  - Gouraud (1971): diffuse lighting
  - Phong (1974): specular lighting
  - Blinn (1974): curved surfaces, texture
  - Catmull (1974): Z-buffer hidden-surface algorithm
  - Crow (1977): anti-aliasing



Computer Graphics: The First 30 Years

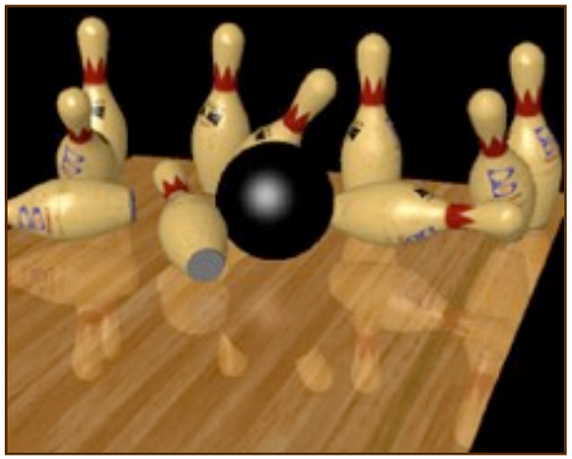
- Basic global shading techniques were developed in the '80s
  - Whitted (1980): ray tracing
  - Goral, Torrance et al. (1984), Cohen (1985): radiosity
  - Kajiya (1986): the rendering equation





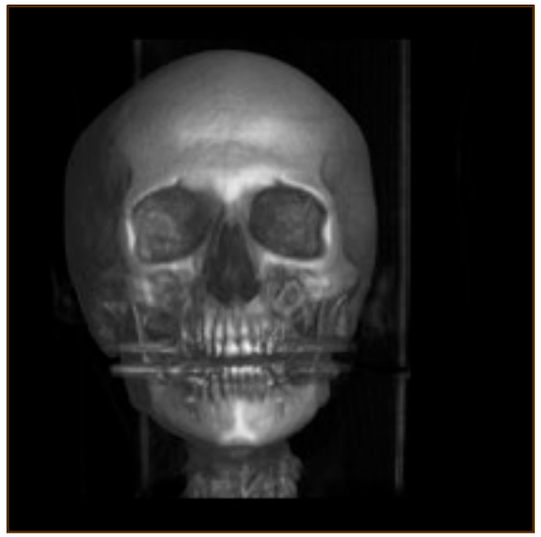
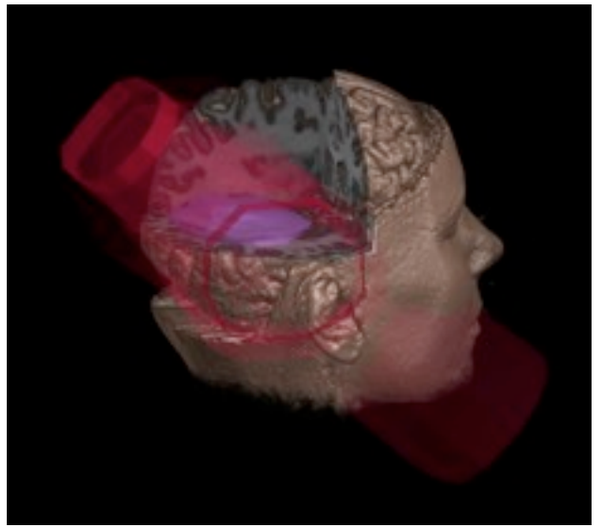
Computer Graphics: The First 30 Years

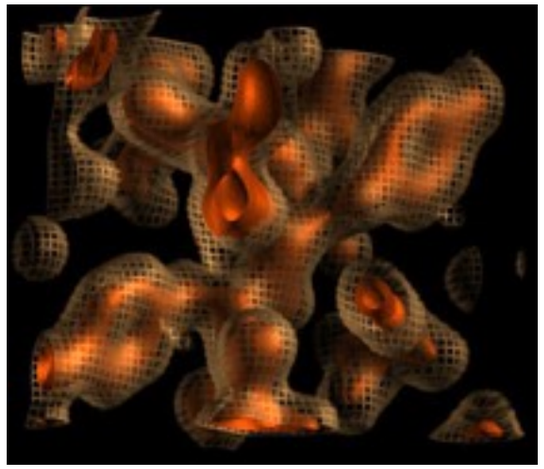
- Later in the '80s and early '90s, the first photorealistic rendering systems were developed
  - Cook (1984): shade trees
  - Perlin (1985): shading languages
  - Hanrahan and Lawson (1990): RenderMan

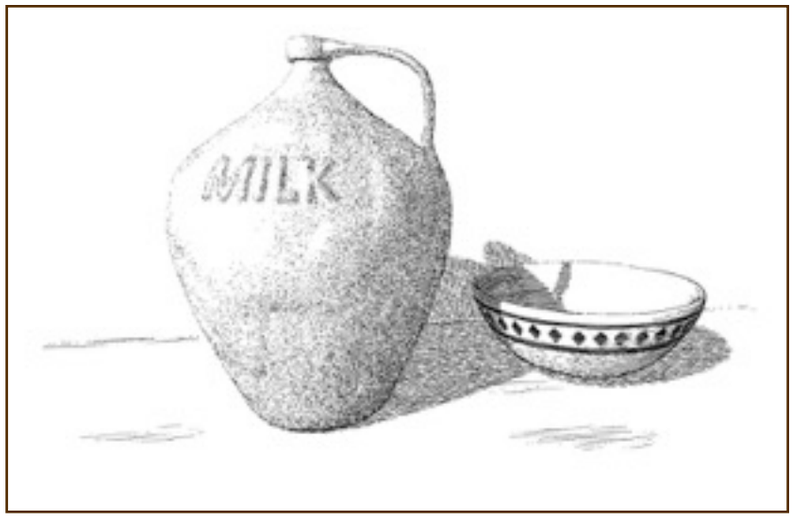


Computer Graphics: The First 30 Years

- Also in the early '90s, the first non-photorealistic rendering techniques were described
  - Drebin et al. (1988), Levoy (1988): volume rendering
  - Haeberli (1990): impressionistic paint programs
  - Salesin et al. (1994-): automatic pen-and-ink illustration
  - Meier (1996): painterly rendering





Look at how far CG has come Today

The Previous 15 Years

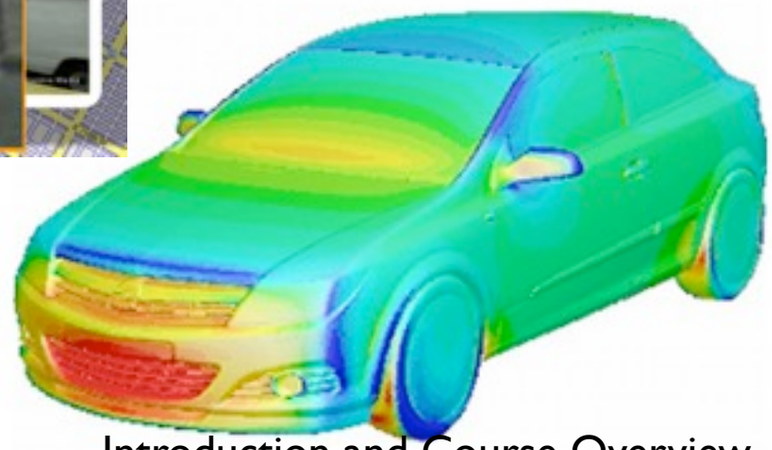
- In the late '90s, the field of computer graphics expands to different directions, including interaction, displays, imagining and computer vison, perception, processing and hardware, and many more
- ACM Siggraph 2015 sessions (37):

  Computational Illumination, Geometry Field Trip, Modeling, Controlling, and Suturing Humans, Face Reality, Rendering Complex Appearance, Wave-Particle Fluidity, VR, Display, and Interaction, Simsquishal Geometry, Let's Do the Time Warp, Meshing Around, Parameterization & Mapping, Video Processing, Deform Me a Solid, Taking Control, Image Processing, Shape Analysis, Fabricating Fabulous Forms, Transfer & Capture, Geometry Zoo, Image Similarity & Search, Reconstruction & Analysis, Fabrication & Function, Appearance Capture, Fluids, From Air to Goo, Procedural Modeling, Character Fashion & Style, Sampling & Filtering, Sketching & Surfacing, Computational Printing, Constraints, Collisions, and Clarinets, Meshful Thinking, Perception & Color, Printing Elastics, Scalable Graphics, Simulating With Surfaces, Light Fields

- Computer Graphics became a really broad field and evolves towards what is now called „visual computing"

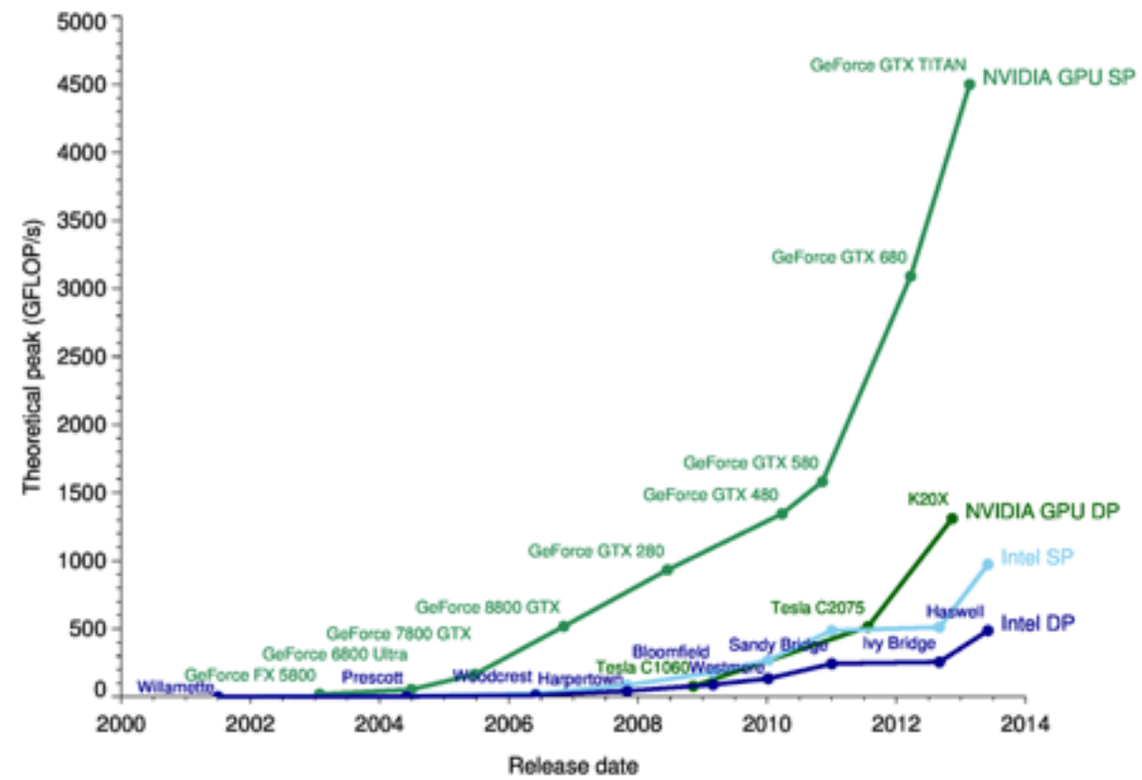
Main Application Areas

- Entertainment (movies and games)
- Information Visualization
- Scientific Visualization (biology, physics, medicine, etc.)
- Computer Aided Design / Computer Aided Manufacturing
- Simulation and Training
- Advertisement
- Traditional (eg., desktop publishing and printing) and new media (WWW: eg. google earth/street view, etc.)



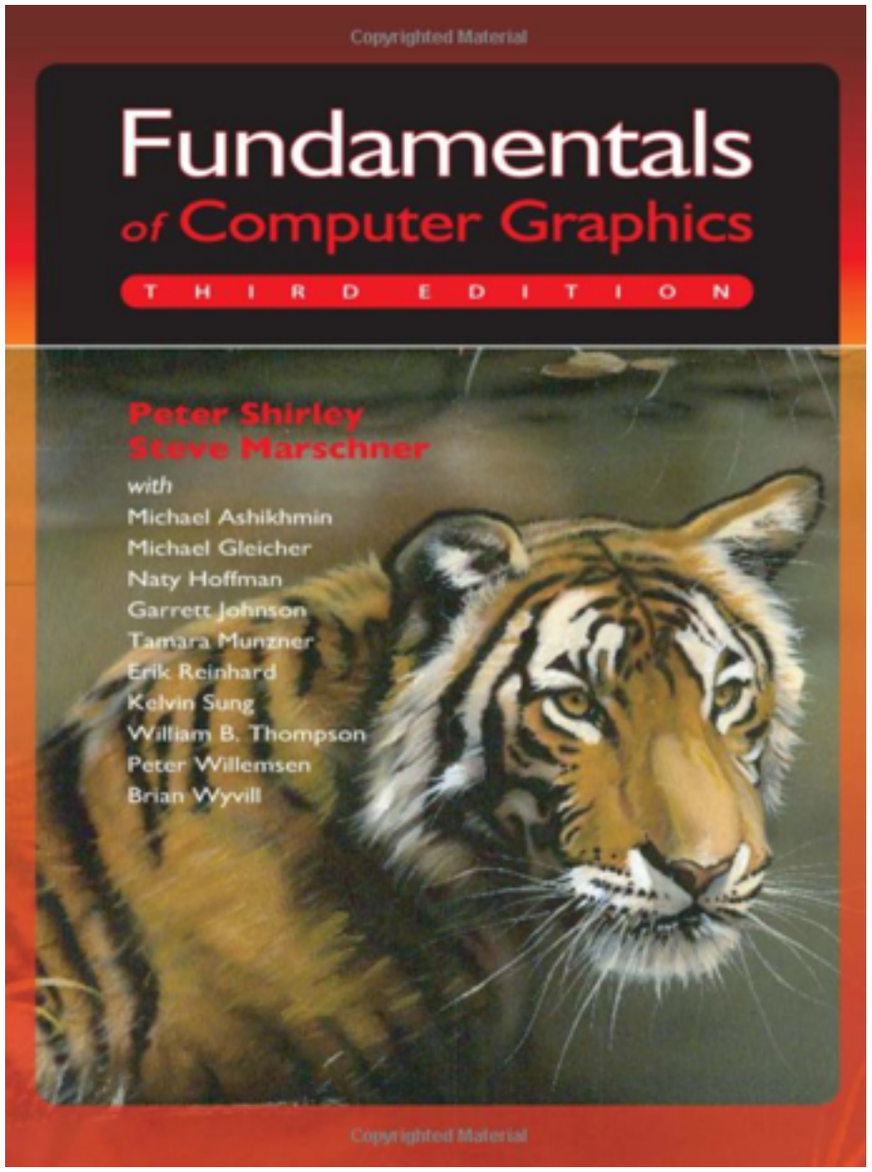
Graphics Processing Power

- In the previous years, commodity graphics processors (GPUs) have evolved from fixed-function graphics units into powerful SIMD (Single Instruction, Multiple Data) processors
- Today, they outperform CPUs by factor >10!
- Multiple GPUs / graphics boards can be combined and run in parallel - resulting in low cost massively parallel computers
- This makes GPUs not only interesting to the computer graphics community, but also to other fields (General-Purpose Computation Using Graphics Hardware, GPGPU -see www.gpgpu.org)



How to Fail the Course

- About 40%-50% of all students failed the course in the previous years
- What to do to fail?
  - just attend the lectures without going through the material frequently to understand it
  - don‘t look at the suggested textbook (or alternative reading material)
  - start preparing for the exams a week before (or even less)
  - only learn slides by heart (without understanding)



about 20 copies available in library
(free scanning possible)

Course Schedule

Type	Date	Time	Room	Topic	Comment
C1	01.03.2016	13:45-15:15	HS 18	Introduction and Course Overview	Conference
C2	15.03.2016	13:45-15:15	HS 18	Transformations and Projections	Easter Break
C3	05.04.2016	13:45-15:15	HS 18	Raster Algorithms and Depth Handling	
C4	12.04.2016	13:45-15:15	HS 18	Local Shading and Illumination	
C5	19.04.2016	13:45-15:15	HS 18	Texture Mapping Basics	
C6	26.4.2016	13:45-15:15	HS 18	Advanced Texture Mapping & Graphics Pipelines	
C7	03.05.2016	13:45-15:15	HS 18	Intermediate Exam	
C8	09.05.2016	17:15-18:45	HS 18	Global Illumination I: Raytracing	
C9	10.05.2016	13:45-15:15	HS 18	Global Illumination II: Radiosity	Conference / Holiday
C10	31.05.2016	13:45-15:15	HS 18	Volume Rendering	
C11	07.06.2016	13:45-15:15	HS 18	Scientific Data Visualization	
C12	14.06.2016	13:45-15:15	HS 18	Curves and Surfaces	
C13	21.06.2016	13:45-15:15	HS 18	Basics of Animation	
C14	28.06.2016	13:45-15:15	HS 18	Final Exam	
C15	04.10.2016	13:45-15:15	TBA	Retry Exam	

Lab Schedule

Type	Date	Time	Room	Topic	Held by
L1	Group 1: 15.03.2016 Group 2: 15.03.2016 Group 3: 11.03.2016 Group 4: 11.03.2016 Group 5: 11.03.2016 Group 6: 11.03.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Introduction to WebGL	Samuel Gratzl + Tutor
L2	Group 1: 05.04.2016 Group 2: 05.04.2016 Group 3: 08.04.2016 Group 4: 08.04.2016 Group 5: 08.04.2016 Group 6: 08.04.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Transformations and Projections	Marc Streit + Tutor
L3	Group 1: 12.04.2016 Group 2: 12.04.2016 Group 3: 15.04.2016 Group 4: 15.04.2016 Group 5: 15.04.2016 Group 6: 15.04.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Scene Graphs	Marc Streit + Tutor
L4	Group 1: 19.04.2016 Group 2: 19.04.2016 Group 3: 22.04.2016 Group 4: 22.04.2016 Group 5: 22.04.2016 Group 6: 22.04.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Shading, Lights and Materials	Samuel Gratzl + Tutor
L5	Group 1: 26.04.2016 Group 2: 26.04.2016 Group 3: 29.04.2016 Group 4: 29.04.2016 Group 5: 29.04.2016 Group 6: 29.04.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Texturing	Clemens Birklbauer + Tutor
L6	Group 1: 03.05.2016 Group 2: 03.05.2016 Group 3: 06.05.2016 Group 4: 06.05.2016 Group 5: 06.05.2016 Group 6: 06.05.2016	Group 1: 15:30-17:00 Group 2: 17:15-18:45 Group 3: 08:30-10:00 Group 4: 10:15-11:45 Group 5: 12:00-13:30 Group 6: 13:45–15:15	S3 063	Advanced Texture Mapping	Clemens Birklbauer + Tutor
L7	CUDA 1: 10.05.2016 VTK 1: 10.05.2016 VTK 2: 13.05.2016 CUDA 2: 13.05.2016	CUDA 1: 15:30-17:00 VTK 1: 17:15-18:45 VTK 2: 08:30-10:00 CUDA 2: 10:15-11:45	S3 063	CUDA VTK (free to choose)	Clemens Birklbauer Marc Streit

Administrative Issues

- We have only 12 PCs in the pool!
- You can bring your own laptop (SW and labs installed), if you don't want to share a PC
  - first labs: shader model 3, DirectX 9 compatible, AIT/Nvidia (no Intel onboard)
  - last lab: shader model 4, Nvidia only
- Groups must be equally balanced
- If you have a conflict with a obligatory course (in B.Sc., not electoral course or private reasons, etc), then email Marc Streit (marc.streit@jku.at)
- In all other cases, switching groups is not possible, unless you find a student to swap with
  - if you find someone to swap with, send an email to marc.streit@jku.at with the two names and group numbers

Administrative Issues

- Classes: 2h weekly, 3 ETCS
- Labs: 2h bi-weekly, 1.5 ETCS, 6 groups
- There is a CG discussion forum in KUSSS that you can use
- Slides and lab material are available on KUSSS: https://www.kusss.jku.at/
- If you are not yet registered, contact Verena Brezina (verena.brezina@jku.at)
- More information on other classes, invited talks, etc.: http://www.jku.at/cg
- Interested in BSc. MS. thesis or practical course, contact me (oliver.bimber@jku.at, see our website for topics)

PC Pool

- You can use the PC pool S3 063 (24/7) if you don't have your own (appropriate) computer and software
  - [Internal] - [Requesting Access to PC-Pool S3 0063]
  - **You must register by this friday (Mar. 7th)**
  - Note, that your Kepler-Card will be registered when you enter the room, and any frauds to the room or equipment can be tracked
  - Do not use the PCs and pool for anything else than your CG exercises
  - Lock the door every time you leave the pool last

Selected Readings

- Fundamentals of Computer Graphics, Peter Shirley and Steve Marschner, A K Peters, ISBN: 1568814690, 2009
- Transformations and Projections in Computer Graphics, David Salomon, Springer, ISBN: 9781846283925, 2006
- Radiosity and Realistic Image Synthesis, Hanrahan and Greenberg, Morgan Kaufmann, ISBN: 0121782700, 1993
- Image Synthesis Theory and Practice, Thalmann, Springer, ISBN: 0387700234, 1988
- Real-Time Shading, Marc Olano, John Hart, and Wolfgang Heidrich, Peters, Wellesley, ISBN: 1568811802, 2002
- Color Imaging: Fundamentals and Applications, Erik Reinhard, Erum Arif Khan, Ahmet Oguz Akyuz, AK Peters, 978-1568813448, 2008
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Thank You!