Introduction to Visualization and Computer Graphics
DH2320

Prof. Dr. Tino Weinkauf

Introduction to Visualization and Computer Graphics and Image/Video Processing

Introduction

DH2320 Introduction to Visualization and Computer Graphics	DD2258 Introduction to Visualization, Computer Graphics and Image/Video Processing
10 joint lectures on visualization and computer graphics	
6 joint homework assignments on visualization and computer graphics	
	2 lectures on image/video
	1 lab assignment on image/video
Joint written exam on visualization and computer graphics	
6 credits	**7.5 credits**

- Tino Weinkauf
  weinkauf@kth.se
  Lindstedtsvägen 5, Room 4420
- Office hours:
  by appointment (e-mail)
- Haibo Li, haiboli@kth.se
  Lindstedtsvägen 3, Floor 6
- Websites:
  - General overview:
    https://www.kth.se/social/course/DH2320/
    https://www.kth.se/social/course/DD2258/
  - Active work, assignments, discussions on Canvas:
    https://kth.instructure.com/courses/4190

- Announcements, schedule, class material:
  https://kth.instructure.com/courses/4190
- The lecture slides are typically available before the lecture.

- Lectures & Tutorials:
  - See schedule for details, but in general:
  - 1-2 Lectures per week
  - 1 Tutorial per week
  - Wednesday and Friday afternoon
  - Location: mainly D3, sometimes in other places. Check the schedule!

- You have to register for the lecture
  - Grading (exercises, exam) requires registration
    - You are welcome to just sit in and listen
    - Registration is required for credits
  - Course registration is open between 8-18 January.
    - For newly admitted students to program term 1: between 16-18 January 2018.

- In some courses at CSC there are PhD-students from other universities in Sweden following the course.
  - Since information, material and communication often is done via KTH systems and the student need a **KTH-account** to sign in these systems these students have had problems to attain the same information as the other students.

- It is possible for **external PhD-students to get a KTH-account**: Go to the reception at CSC at Lindstedtsvägen 3, level 4, where you can sign a form.

- It will only take a few days to get the account.

- **Disability**
  - *Support via Funka*
    If you have a disability, you may receive support from Funka.
    https://www.kth.se/en/student/studentliv/funktionsnedsattning
  - *Inform the teacher*
    We recommend that you inform the teacher regarding any need you may have. Funka does not automatically inform the teacher.

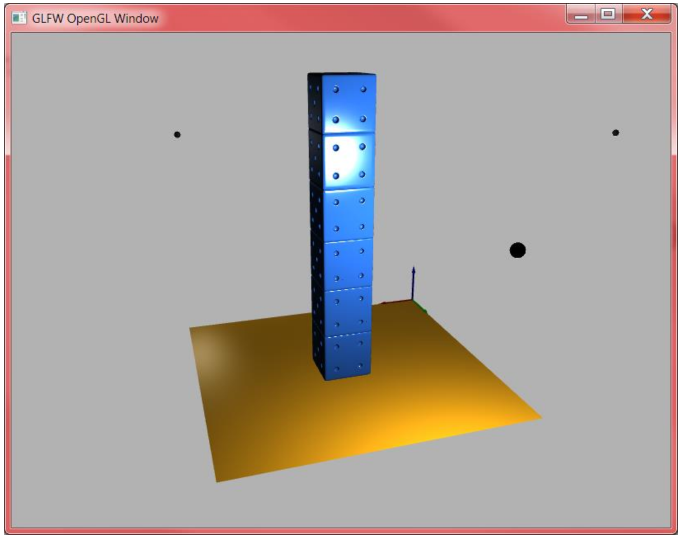
- **Funktionsnedsättning**
  - Om du har en funktionsnedsättning kan du få stöd via Funka:
    https://www.kth.se/student/studentliv/funktionsnedsattning
    Informera dessutom kursledaren om du har särskilda behov. Visa då upp intyg från Funka.

- To pass the lecture, you need to...
    - Work on **all homework assignments**
    - Obtain at least **50%** of the assignments score
    - **Pass** the final written exam
        - DH2320: Pass / Fail
        - DD2258: A-F
- DH2320: 6 CP
- DD2258: 7.5 CP

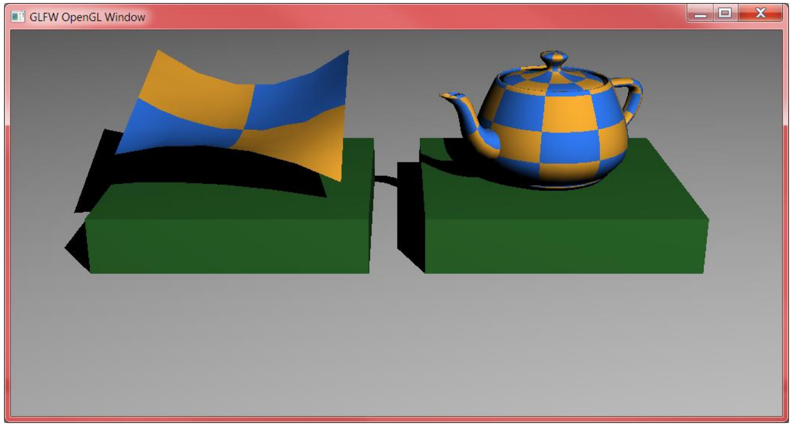
- Concept
  - Theory & practice
- Theoretical Assignments
  - Each student must prepare a write-up
  - Hand-in solutions on paper (written, printed) before they are discussed in class
  - Will be returned a week later
  - Solutions will be discussed in the tutorial course

- Practical Assignments
  - Programming assignments
    - Group work: **groups of approx. three students**

  - A C++ framework will be provided (Linux/Windows/Mac)
    - Windows users:
      Visual Studio Express is available for free download
      Other versions of Visual Studio are available through Microsoft Imagine
      https://intra.kth.se/en/it/programvara/microsoft-imagine-1.675383
    - Linux users:
      Multiple options: Console, K-Develop, QT Creator
    - Mac users:
      XCode



Linear Transformations



Advanced Raytracing

Volume Rendering

- Practical Assignments: Grading
  - Grading in peer review
  - Group must show up entirely
  - Randomized assignment of pairs of groups
    - A grades the work of B
    - B grades the work of C
  - Everybody is graded individually, based on:
    - The group’s implementation
    - Personal knowledge about the implementation
    - Everybody must be able to explain all of the code

- Anke Friederici
  - ankef@kth.se
  - LV 5, Room 4424

- Wiebke Köpp
  - wiebkek@kth.se
  - LV 5, Room 4424

- Practical Assignments
  - Groups of three students
    - Form groups yourselves
    - Need to be formed by week 4, i.e., next week
  - Signup in Canvas for groups:
    Open for signup today.
  - Bring your own equipment (laptop)
    - Possible for everyone?

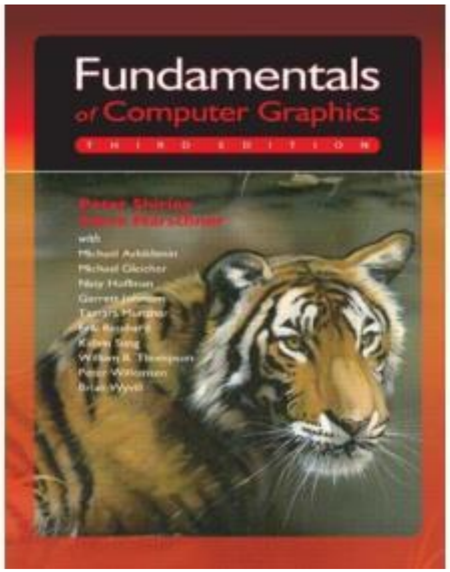
- First Tutorial courses:
  - Using the programming environment (personal advice)
  - Introduction to the provided C++ framework
  - Help with forming groups
  - **Bring your laptop!**

- Introduction to Inviwo / CMake / Visual Studio / Compiling:
  Friday, Jan 19, 15-17 in E35 & E36

- Introduction to C++ Programming / CMake / Visual Studio / Compiling:
  Friday, Jan 26, 15-17 in Q15 & Q17

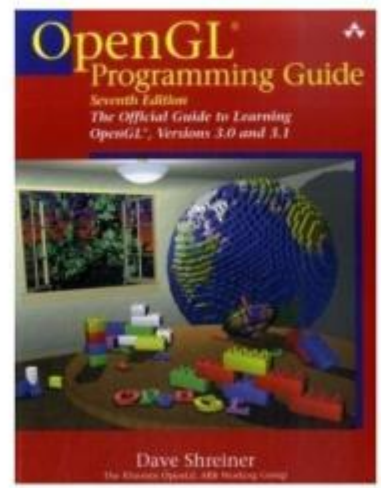
- Written exam
  - 2 hours
  - Similar to theoretical homework assignments
- Exam date: Saturday, March 17, 2018, 9:00-11:00
- Re-Exam date: Wednesday, April 4, 2018, 8:00-10:00

- Questions & Suggestions
  - Please let us know if there are any issues anytime
  - We appreciate your feedback! Please let us know:
    - ...if you find a certain part of the lecture hard to understand or not well explained.
    - ...any suggestions how to improve the lecture or the exercises.
    - ...any other questions, suggestions or concerns.
  - Office hours: Appointments can be coordinated via e-mail



Peter Shirley
Fundamentals of Computer Graphics
AK Peters, 3. Edition

Dave Shreiner
OpenGL Programming Guide
Morgan Kaufmann, 7. Edition



- Books (cont‘d)
  - J. D. Foley, A. van Dam, S. K. Feiner, J. F. Hughes: Computer Graphics - Principles and Practice (second Edition). Addison-Wesley Publishing Company, Inc., 1996
  - D. Salomon: Computer Graphics Geometric Modeling, Springer, 1999
  - A. Watt: 3D Computer Graphics. Addison-Wesley Publishing Company, Inc., 2000
- Journals
  - Computer Graphics Forum
  - IEEE CG & Applications
  - ACM Transactions on Graphics
  - ACM Transactions on Visualization and Computer Graphics

The lecture slides are partly based on material from

- Prof. Holger Theisel (Universität Magdeburg)
- Prof. Michael Wand (Universität Mainz)
- Prof. Heidrun Schumann (Universität Rostock)
- Prof. Marcus Magnor (Universität Braunschweig)
- Jun.-Prof. Thorsten Grosch (Universität Magdeburg)

- ...and other colleagues.
- Thanks!

- Tino Weinkauf
- Studied computer science in Rostock, Germany
  - Special focus: computer graphics and visualization
- Worked at Zuse Institute Berlin, Germany (2001 – 2009).
  - Flow analysis and visualization
- Received PhD in computer science (Dr. Ing.) from University of Magdeburg, Germany (2008).
- Post-doc at New York University, U.S.A. (2009 – 2011)
  - Feodor Lynen fellowship from the Alexander von Humboldt foundation
- Head of independent research group at Max-Planck-Institute for Informatics, Saarbrücken, Germany (2011 – 2014)
- Professor of Visualization, KTH Stockholm (since 2015)
- Research interests: Visualization, Data Analysis, Computer Graphics, Topology, Geometric Modeling, Shape Analysis

- Name
- Where do you come from?
- Where did you do your Bachelor?
- In wha
  - Mast
  - Mast
  - Mast
  - Mast
  - Mast
  - Something else?

https://goo.gl/forms/JXpxxCJeheSAW2Fz1

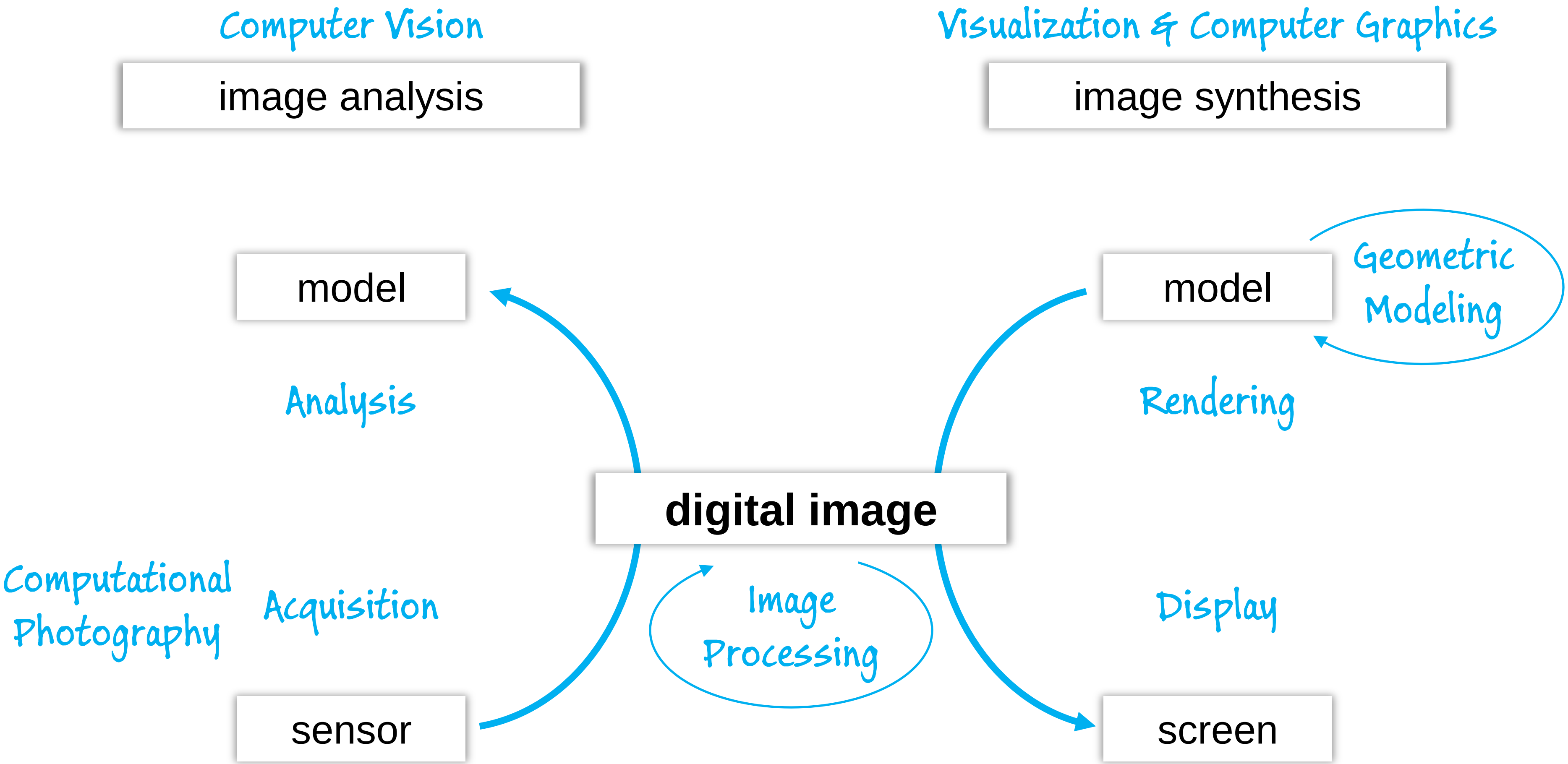
Introduction to Visualization and Computer Graphics

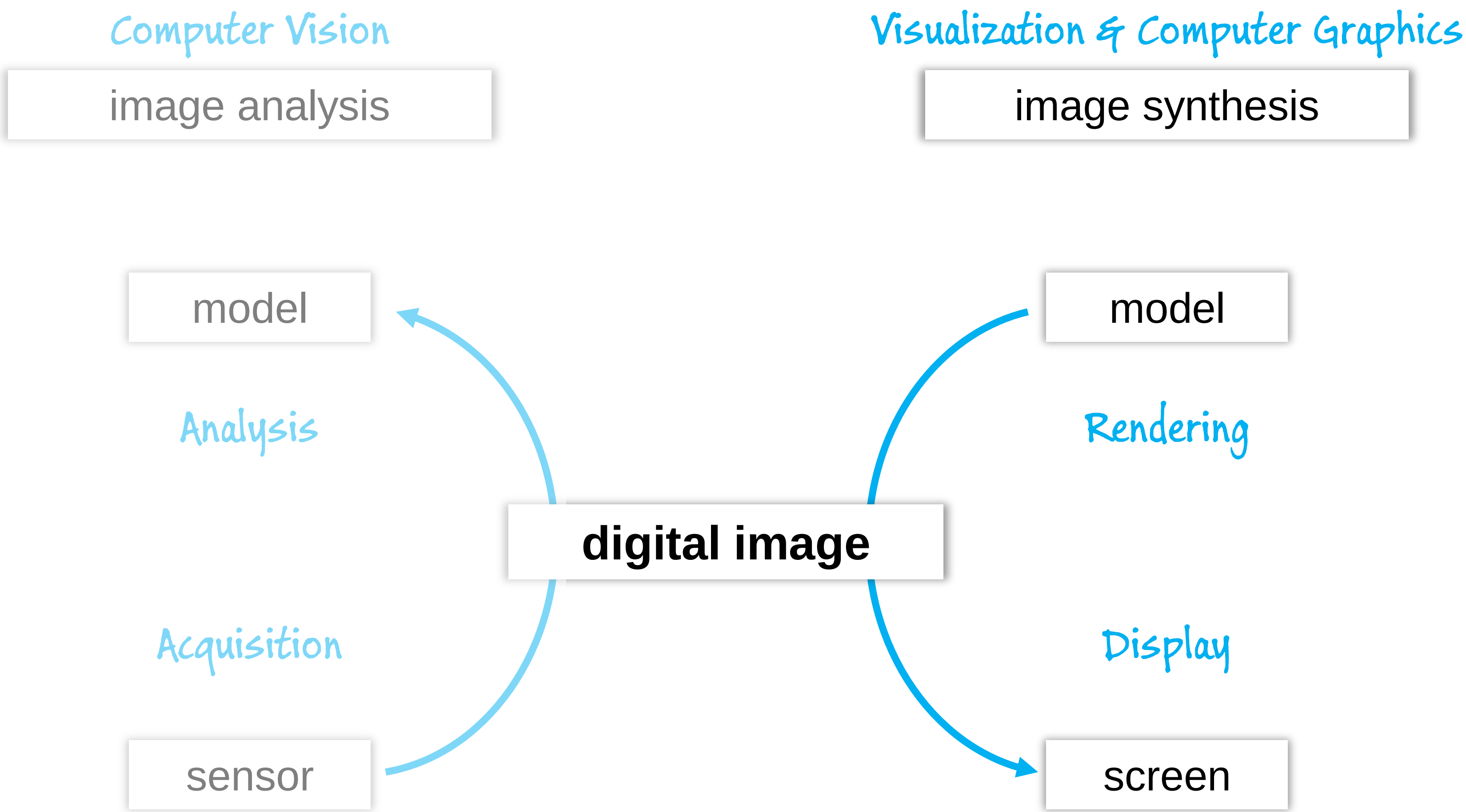
Terms and Definitions

Visual Computing is the field of

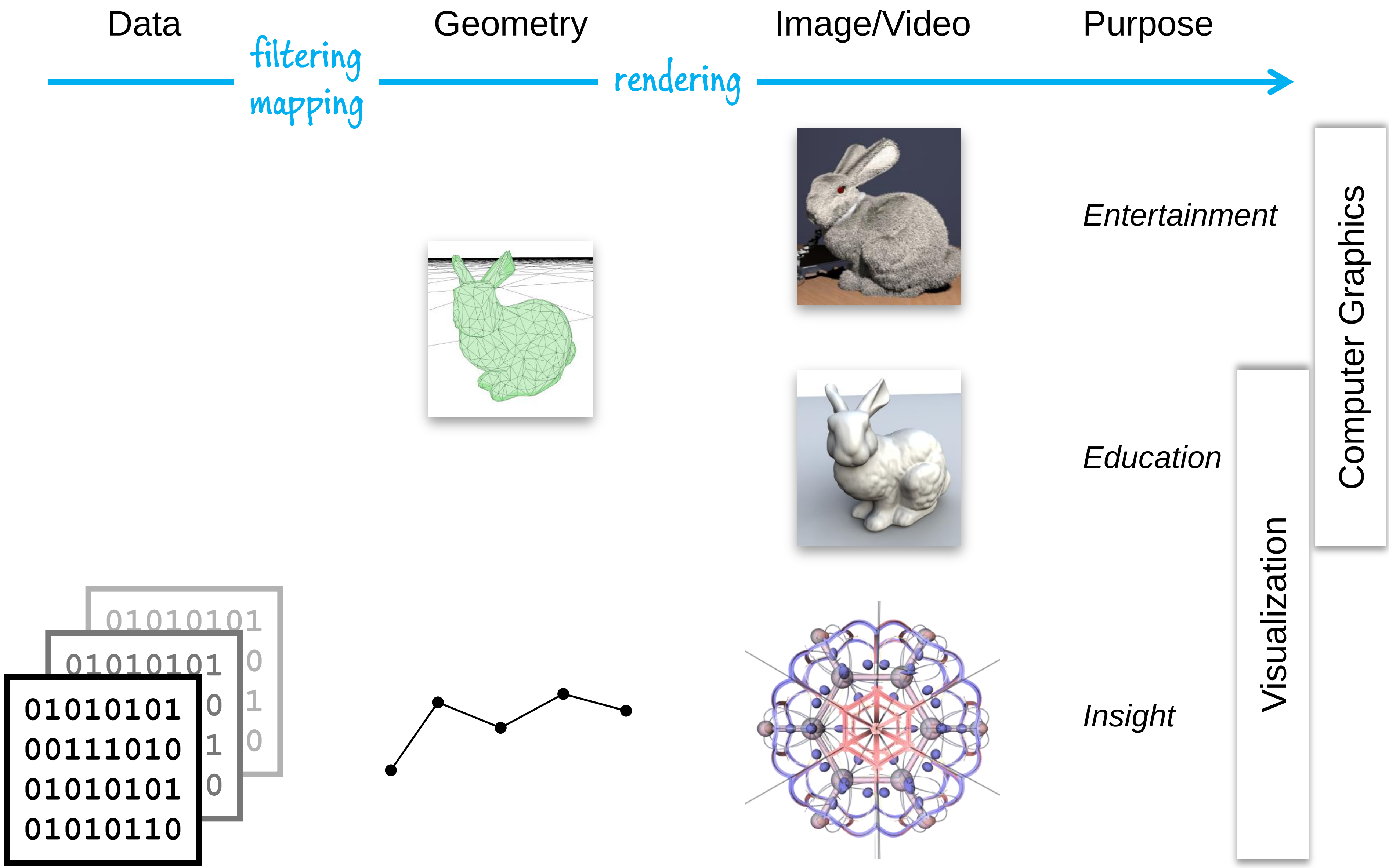
- acquiring,
- analyzing,
- processing, and
- synthesizing

visual data by means of computers.


Computer Vision
image analysis
Visualization & Computer Graphics
image synthesis
model
Analysis
model
Geometric Modeling
Rendering
digital image
Computational Photography
Acquisition
Image Processing
Display
sensor
screen


Computer Vision
image analysis
Visualization & Computer Graphics
image synthesis
model
Analysis
Acquisition
sensor
digital image
model
Rendering
Display
screen

Pipeline for Visualization and Computer Graphics



Introduction to Visualization and Computer Graphics

Applications

- Games
  - Has to “look” good
  - Natural phenomena
  - Ad-hoc techniques are ok
  - For example: textures & shaders to “fake” details

Crysis 2, PC 2011

- Movies
  - Has to “look” good
  - Natural phenomena
  - Ad-hoc and physically based methods
  - Often rendering times of 1000 hours for a single frame!

Avatar, 2009

- Landscape Planning
  - Realistic rendering of plants for planning and virtual tours

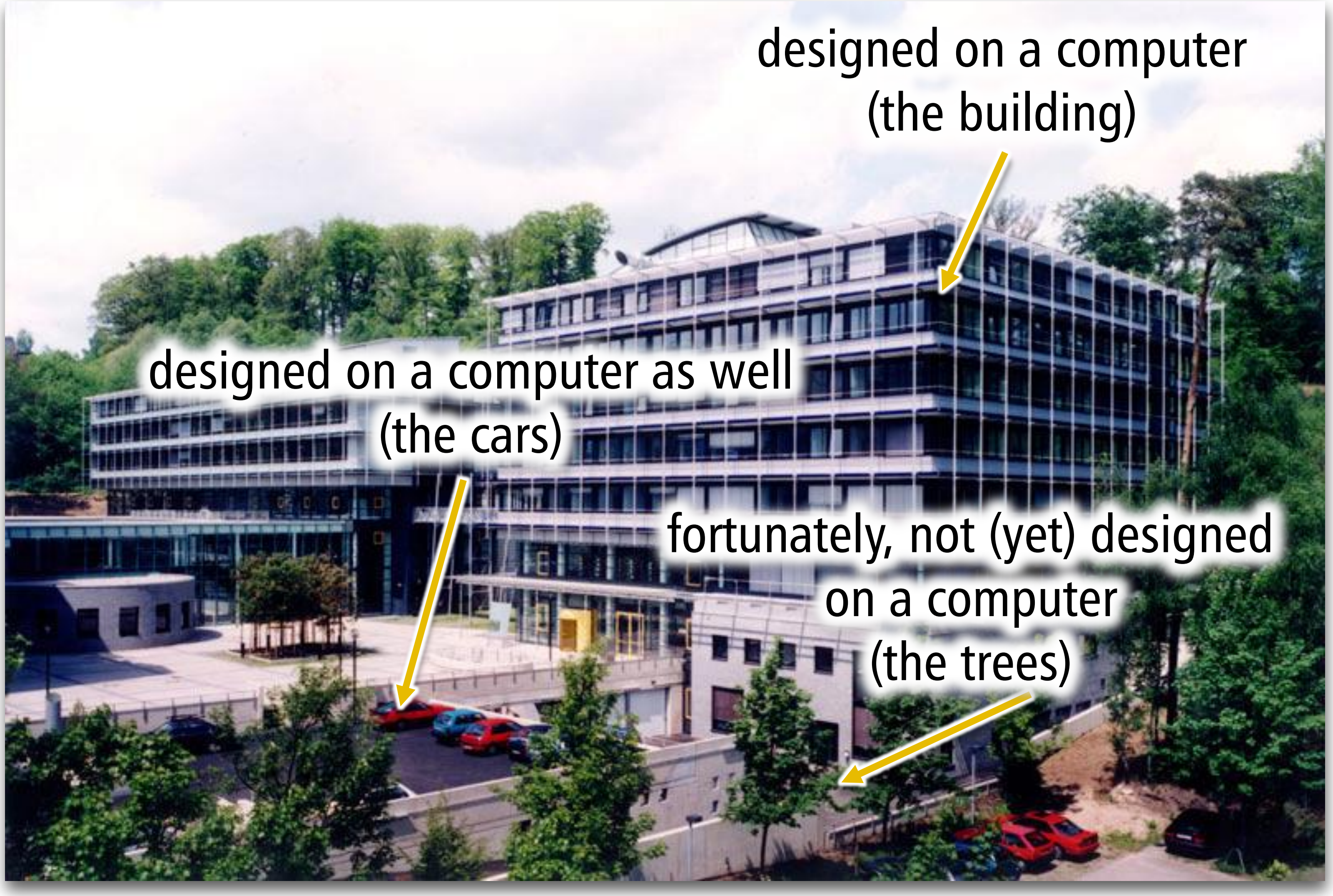
[www.laubwerk.com, 2015]

- Training
  - Flight simulator
  - Driving simulator

[www.flugsimulator.com, 2015]

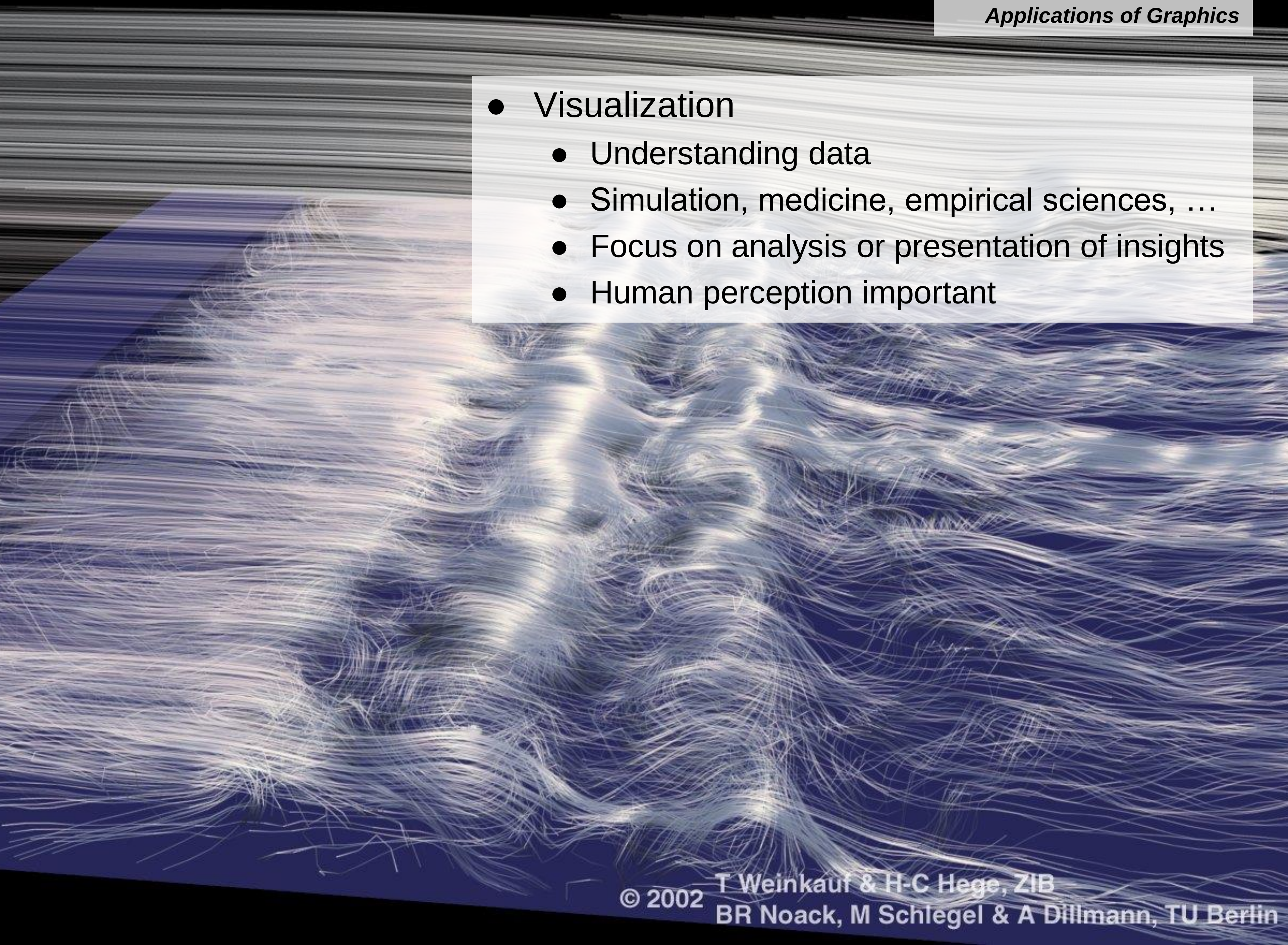
- CAD / CAM
  - Precision Guarantees
  - Geometric constraints (e.g. exact circles)
  - Modeling guided by rules and constraints

[aimatshape.net]

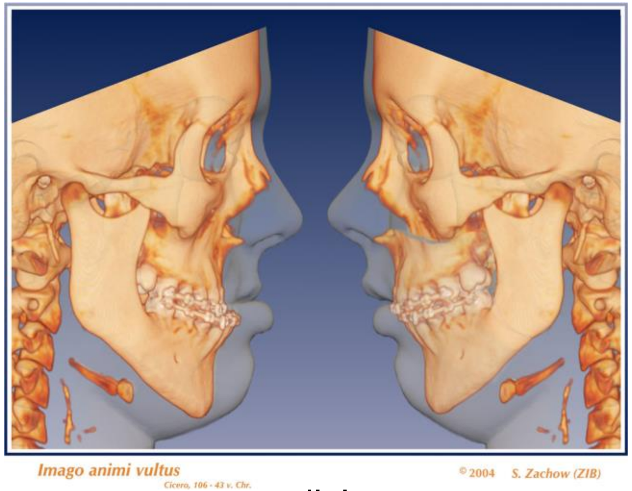


[c.f. Danny Hillis, Siggraph 2001 keynote]

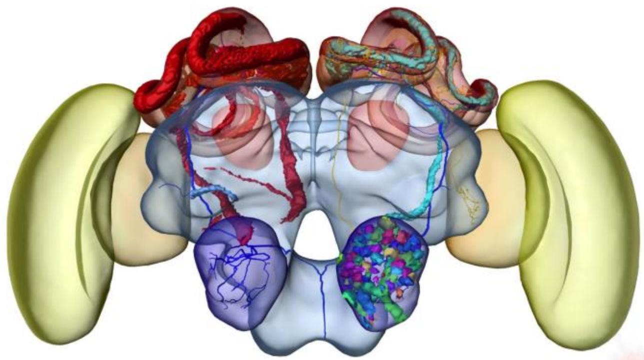
- Visualization
  - Understanding data
  - Simulation, medicine, empirical sciences, …
  - Focus on analysis or presentation of insights
  - Human perception important



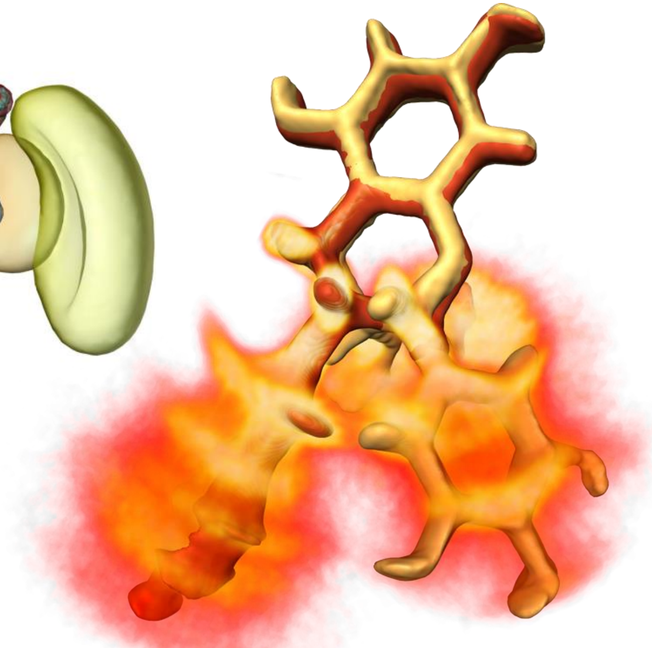
(Some) Applications of Visualization



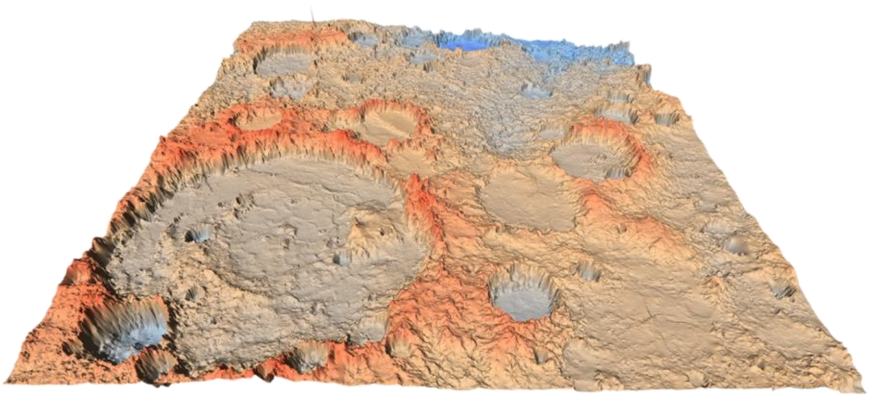
medicine



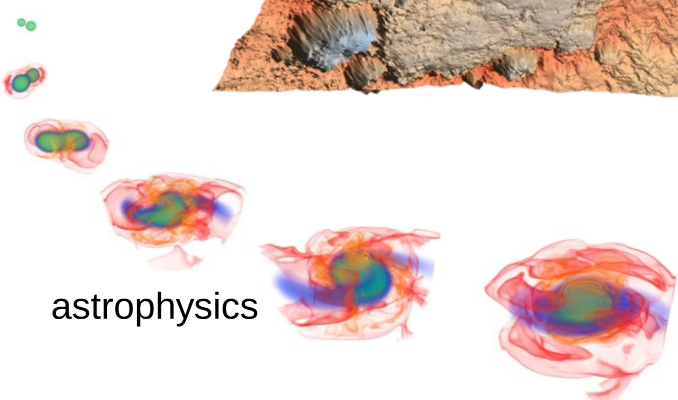
biology



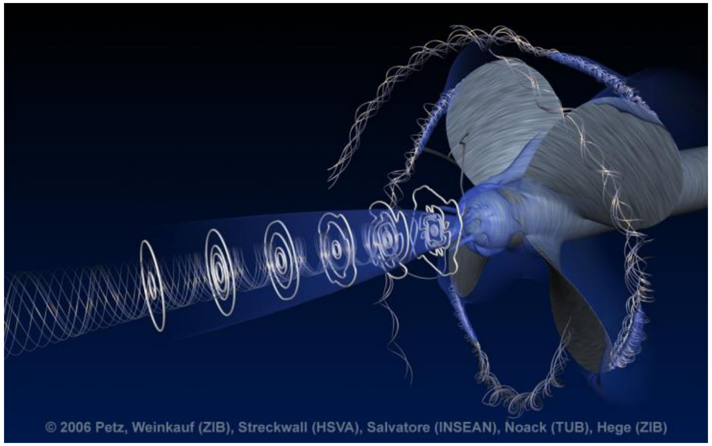
pharmacology



planetology



astrophysics



engineering

Introduction to Visualization and Computer Graphics

History

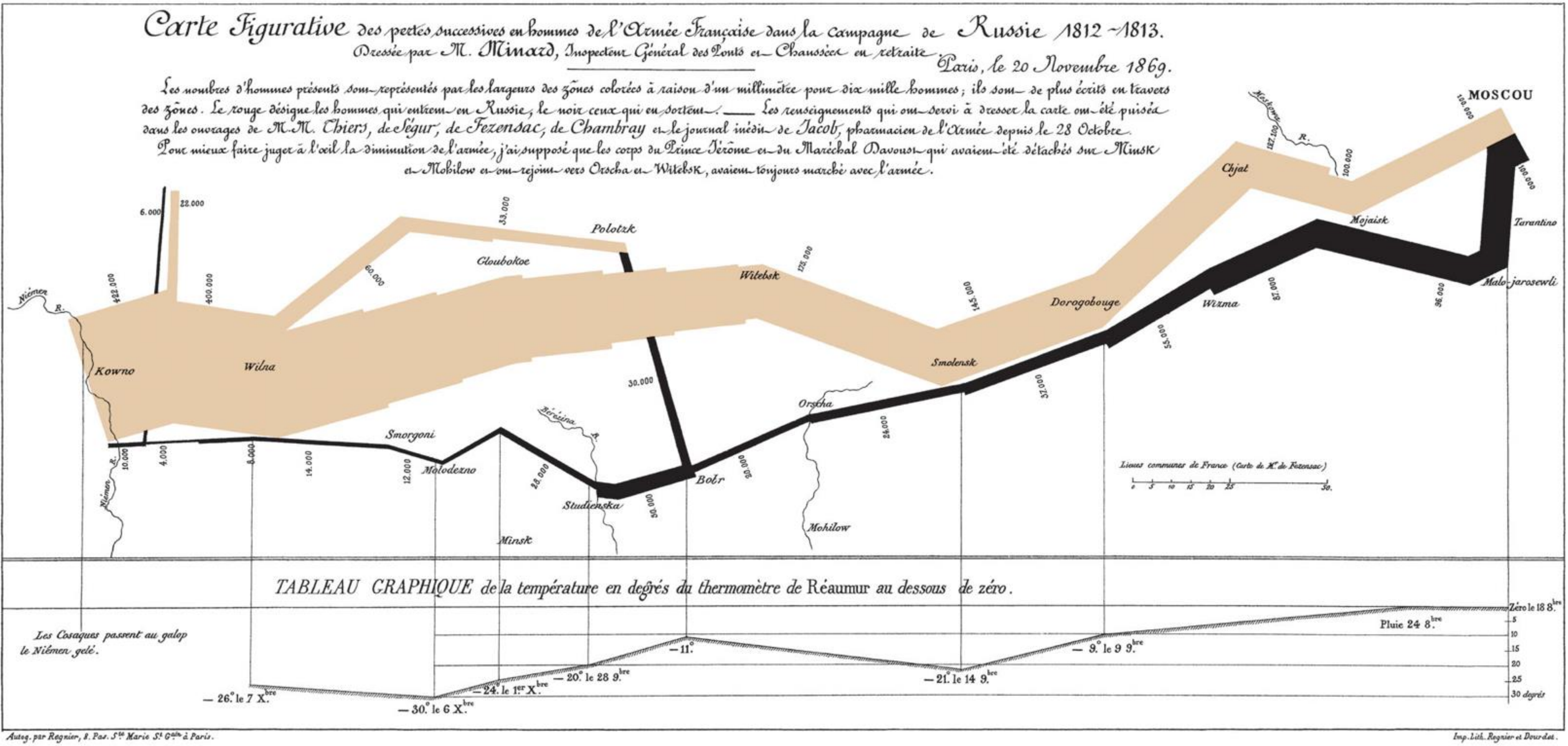
- Idea of visualization very old
- **Euclid's "Elements**": drawings to represent and illustrate properties in geometry.
- **Middle Ages**: astronomical maps with arrow plots to visualize prevailing winds over the oceans.
- **18th century**: height lines used in topographical maps

- **Alexander von Humboldt** (German scientist and explorer, 1769 – 1859)

  Investigations of temperature gradients on the northern hemisphere. (1817)

- **René Descartes** (French philosopher, mathematician, physicist, 1596 – 1650)

  ”Imagination or visualization, and in particular the use of diagrams, has a crucial part to play in scientific investigations”. (1637)

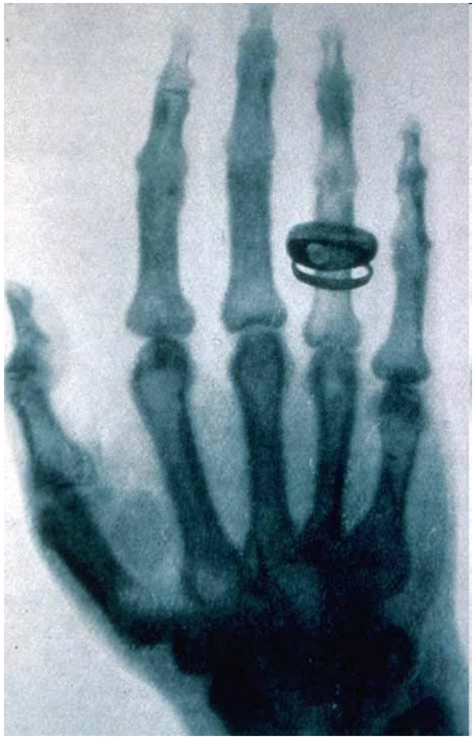


1869 Cartography by Charles Joseph Minard

Napoleons campaign against Russia (1812/13)

- **Wilhelm Conrad Röntgen** (German physicist, 1845 – 1923)

  X-rays (1895)
  first Nobel Prize in Physics (1901)



- **Rosalind Franklin** (British biophysicist, 1920 – 1958)

  X-ray diffraction images of DNA (1952)

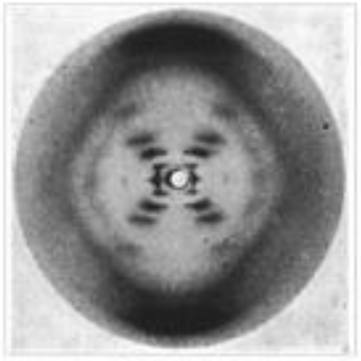
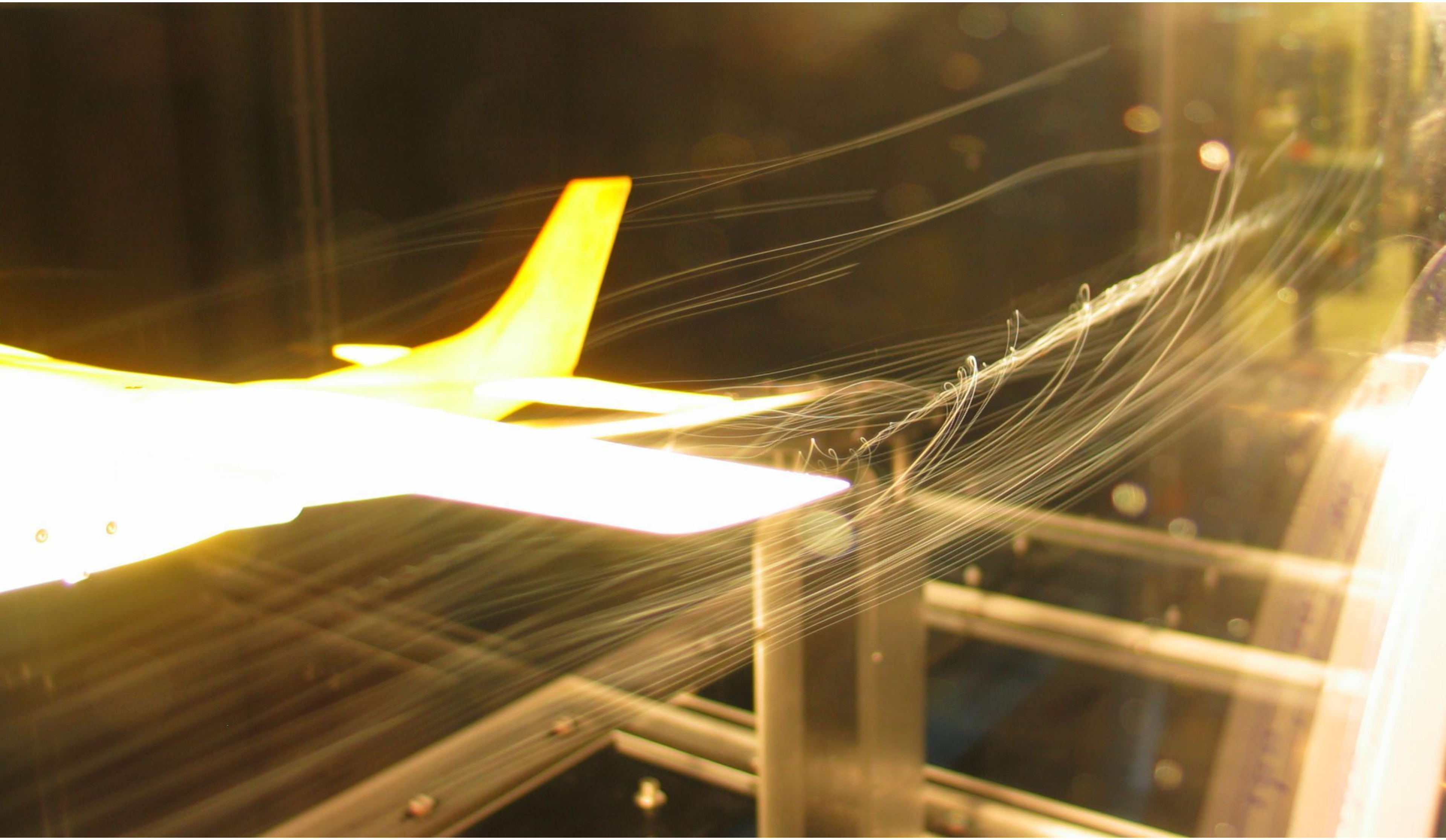


Photo 51
X-ray diffraction image of sodium salt of DNA. B configuration

Nobel prize went to Watson, Crick, and Wilkins in 1962


Milestones in Flight History
Dryden Flight Research Center
NASA
C-5A
Wing Vortice Tests at Langley
Circa 1970s

Smoke angel
A C-17 Globemaster III from the 14th Airlift Squadron, Charleston Air Force Base, S.C. flies off after releasing flares over the Atlantic Ocean near Charleston, S.C., during a training mission on Tuesday, May 16, 2006. The "smoke angel" is caused by the vortex from the engines.
(U.S. Air Force photo/Tech. Sgt. Russell E. Cooley IV)

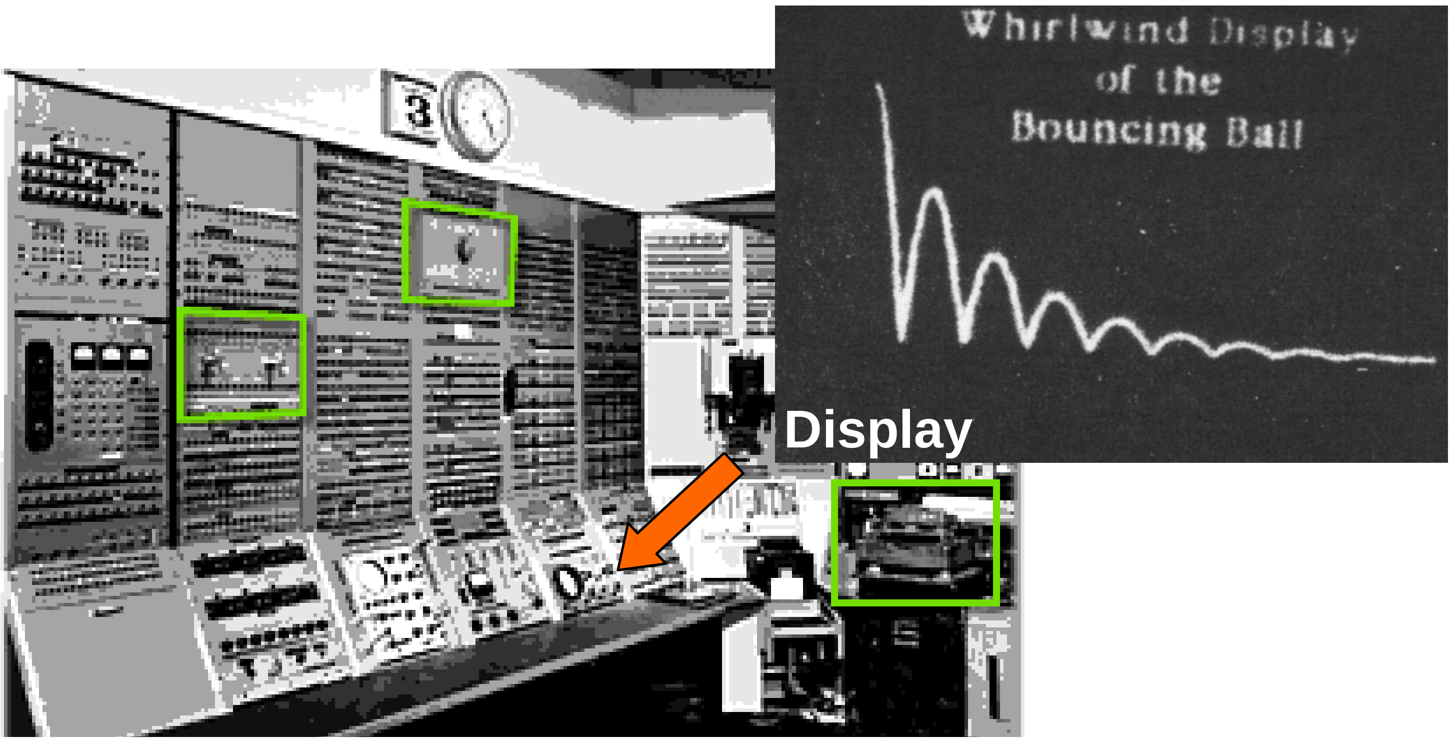


A wind tunnel model of a Cessna 182 showing a wingtip vortex.
Tested in the RPI (Rensselaer Polytechnic Institute) Subsonic Wind Tunnel.
By Ben FrantzDale (2007).

- upcoming computer technology: new challenges!
- virtual experiments, where the real ones are too expensive or dangerous
- larger data sets
- new opportunities to create visual representations (Computer Graphics)
- 1987: Visualization becomes discipline of its own
  - 1987 Marching Cubes
  - 1987 Parallel Coordinates
  - 1989 Vector Field Topology
  - 1993 Line Integral Convolution

- Since 1990: annual IEEE Visualization Conference
- Since 1999: annual Eurographics Symposium/Conference on Visualization (EuroVis)
- journals, books...
- many research groups worldwide, strong funding

- 1949:
  First computer graphics on the *whirlwind* computer at MIT
  - *Bouncing Ball* program of C. Adams



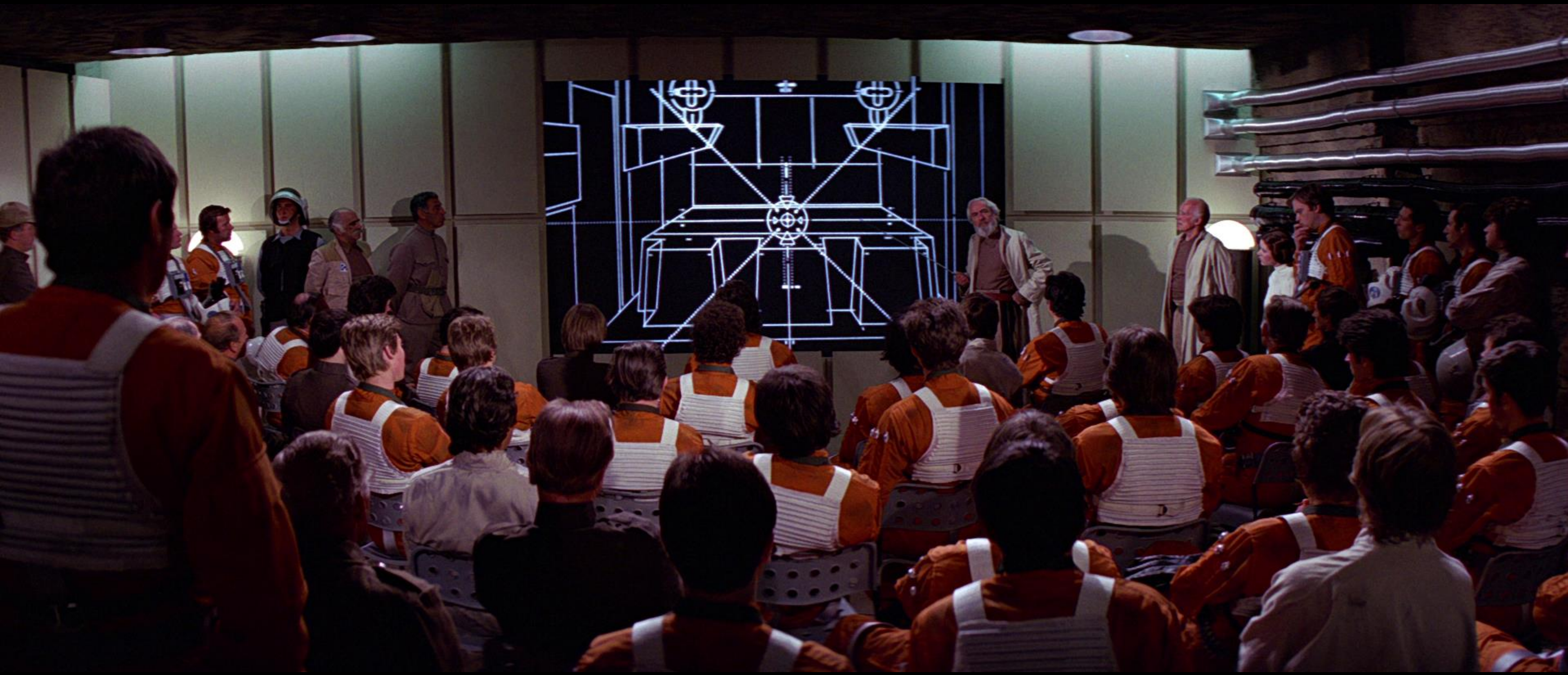
- 1952:
  Indication of flying objects on radar screens
  - *SAGE* computer with 82 graphics consoles for air control
  - First use of the light pen

- Beginning of the 70s: first commercial CAD/CAM systems

- 1973: first ACM SIGGRAPH conference
  - SIGGRAPH: Special Interest Group on Computer Graphics
  - ACM: Association of Computing Machinery
  - 1200 participants in 1973
  - Now: approx. 20000 participants

*1975: M. Newell (Univ. of Utah) models the **Utah tea pot** – a computer graphics icon.*

Star Wars (1977)



Tron (1982)

Koronis Rift (C64, 1985)

Luxo Jr. (1986)

(c) Pixar

Stunt Car Racer (Amiga, 1989)

The Abyss (1989)

Terminator II (1991)

Comanche (PC, 1992)

(c) Nova Logic

Doom (PC, 1993)

(c) id Software

Toy Story (1995)

(c) Pixar

Quake (PC, 1996)

(c) id Software

Final Fantasy (2001)

The Lord of the Rings (2002)

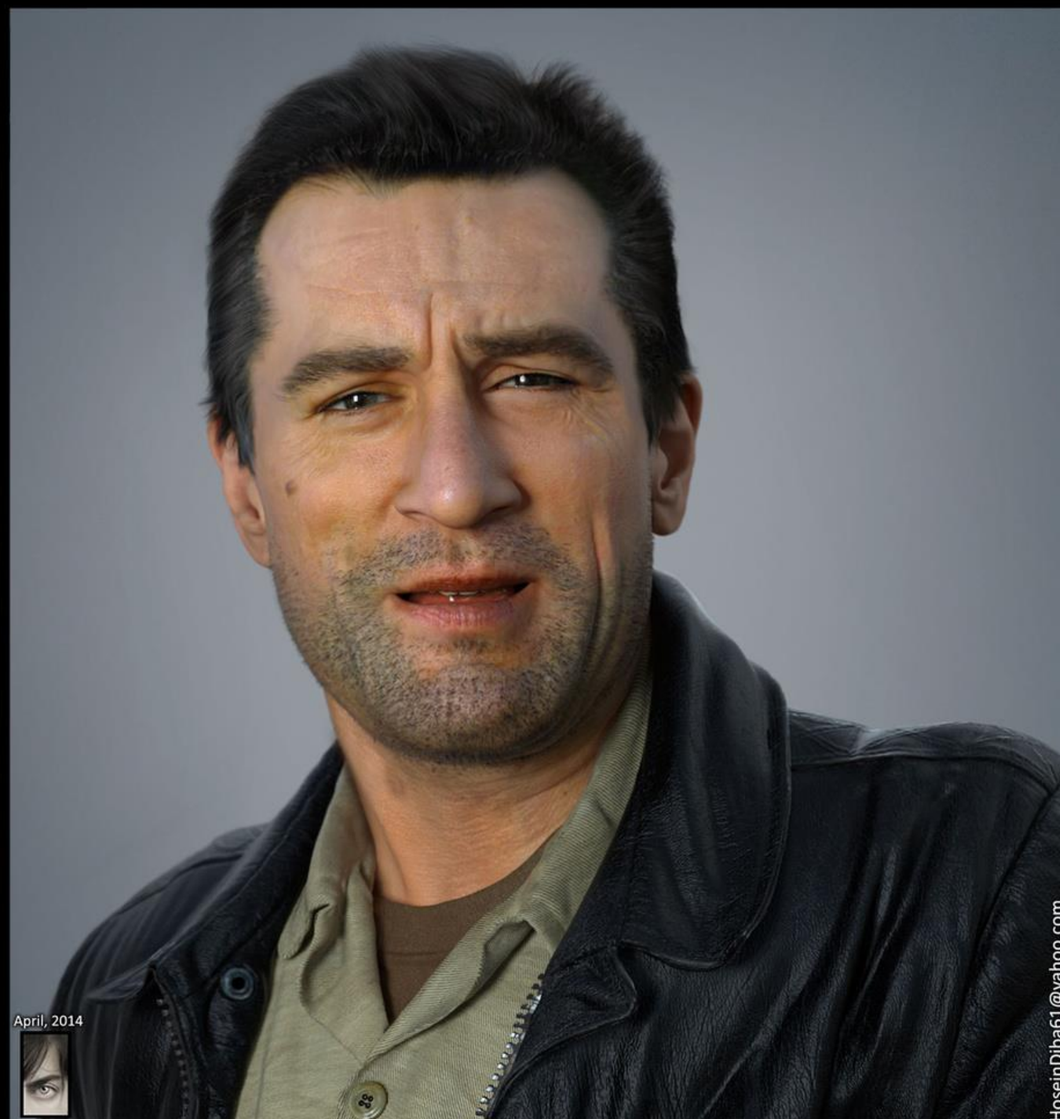
Avatar (2009)

(c) 20th Century Fox

Crysis 2 (PC, 2011)

(c) Crytek

Last Night on Reddit (2014)



(c) Hossein Diba

Introduction to Visualization and Computer Graphics

Strong research leads to strong results

“Point-based Global Illumination”

Pixar, Industrial Light & Magic


Point-Based Approximate Color Bleeding

Per H. Christensen
Pixar Technical Memo #08-01
Pixar Animation Studios

Abstract

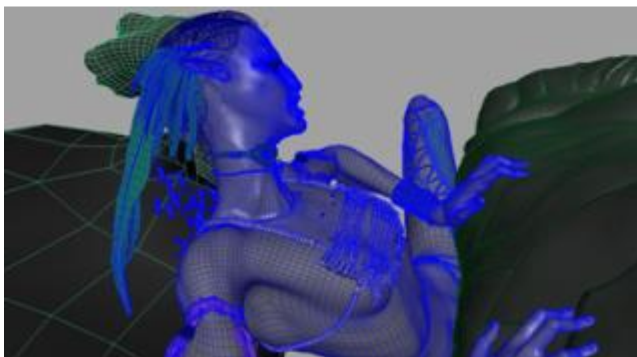
1 Introduction

[Fluch der Karibik 2, 2006]

“PantaRay – Visibility Precomputing”

Nvidia, Weta Digital

[Avatar, 2009]



PantaRay: Fast Ray-traced Occlusion Caching of Massive Scenes

Abstract

1 Introduction

“Volumetric Lighting”

Disney Research

[Rapunzel, 2010]

A Programmable System for Artistic Volumetric Lighting

Abstract

1 Introduction

“Out-of-Core Global Illumination”

DreamWorks Animation

[Kung Fu Panda 2, 2011]


Coherent Out-of-Core Point-Based Global Illumination

“Artistic Simulation of Curly Hair”

Disney, Pixar

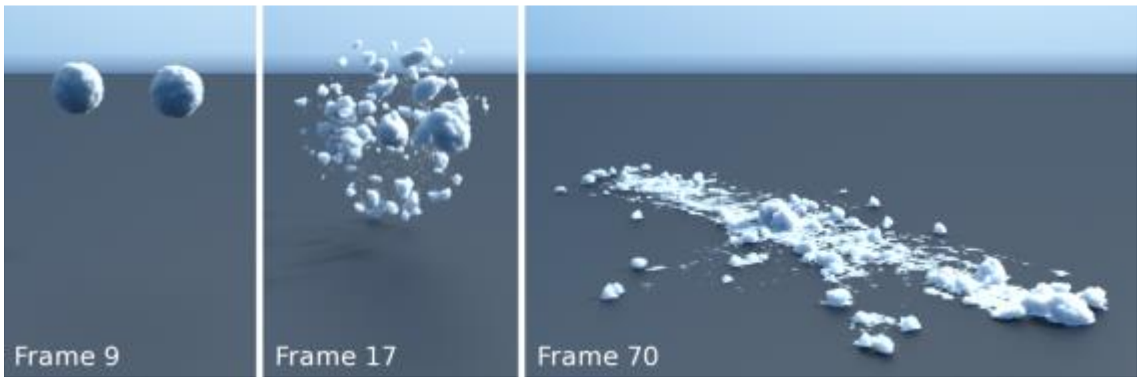
[Merida, 2012]


Artistic Simulation of Curly Hair

“Simulation of Snow”

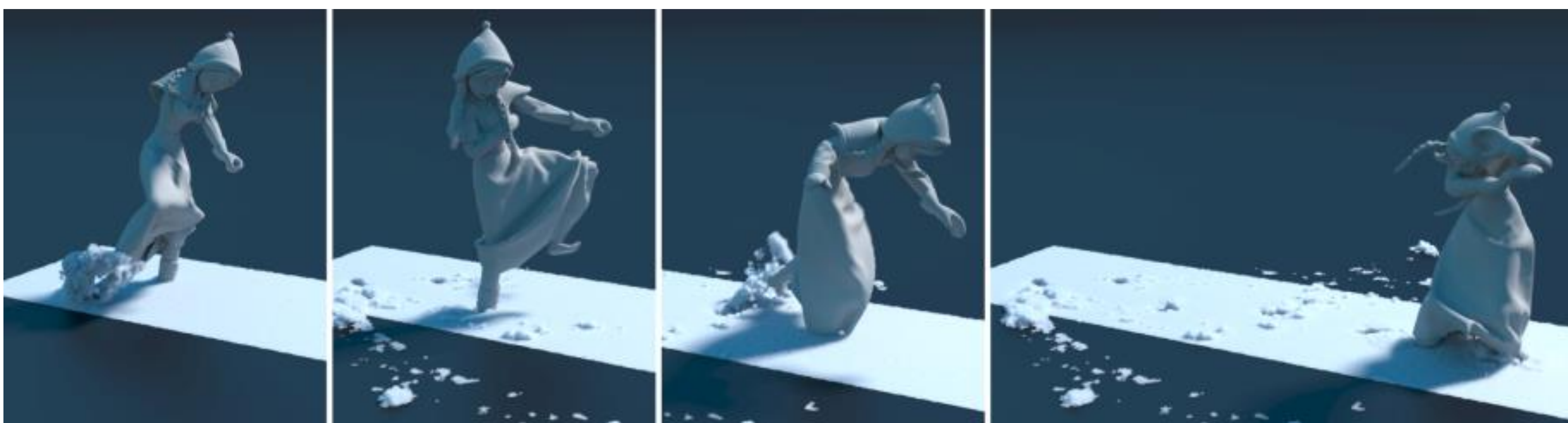
Disney, Pixar

[Eiskönigin, 2013]




Abstract

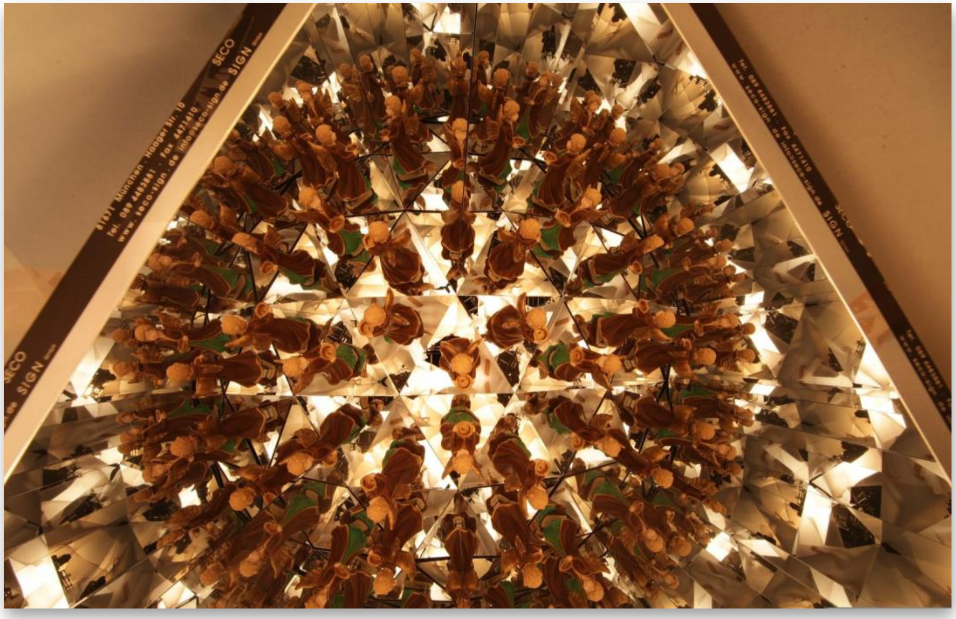
1 Introduction



Introduction to Visualization and Computer Graphics

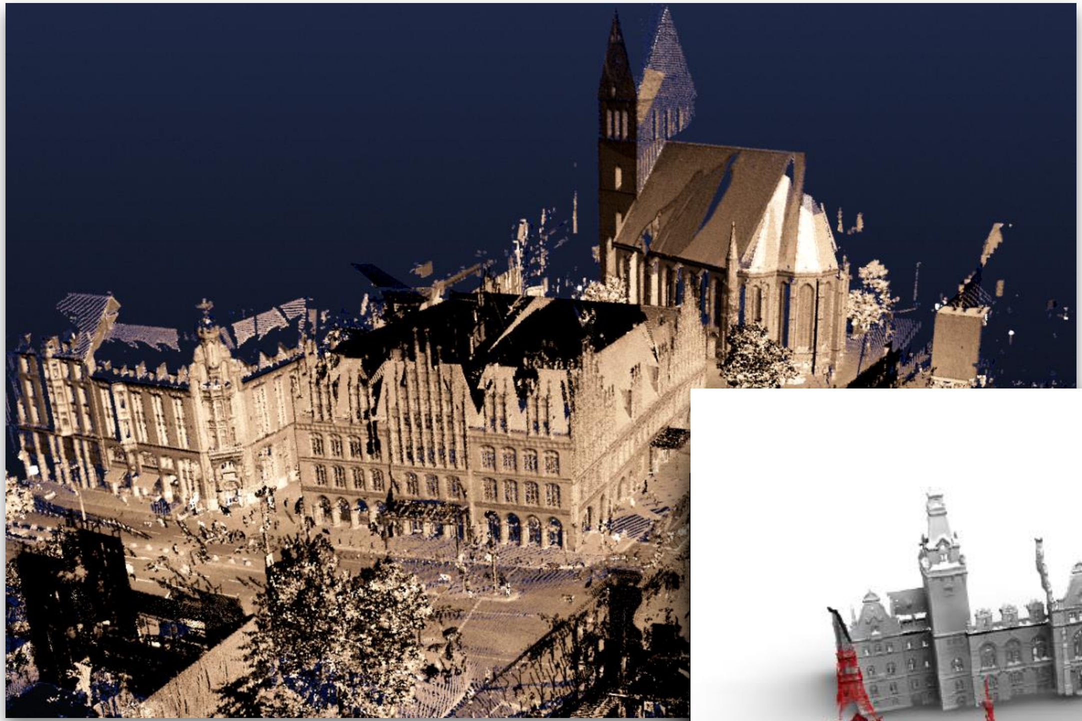
Trends

- Learning from real-world data
  - Complexity of reality
  - Machine learning + physical measurement

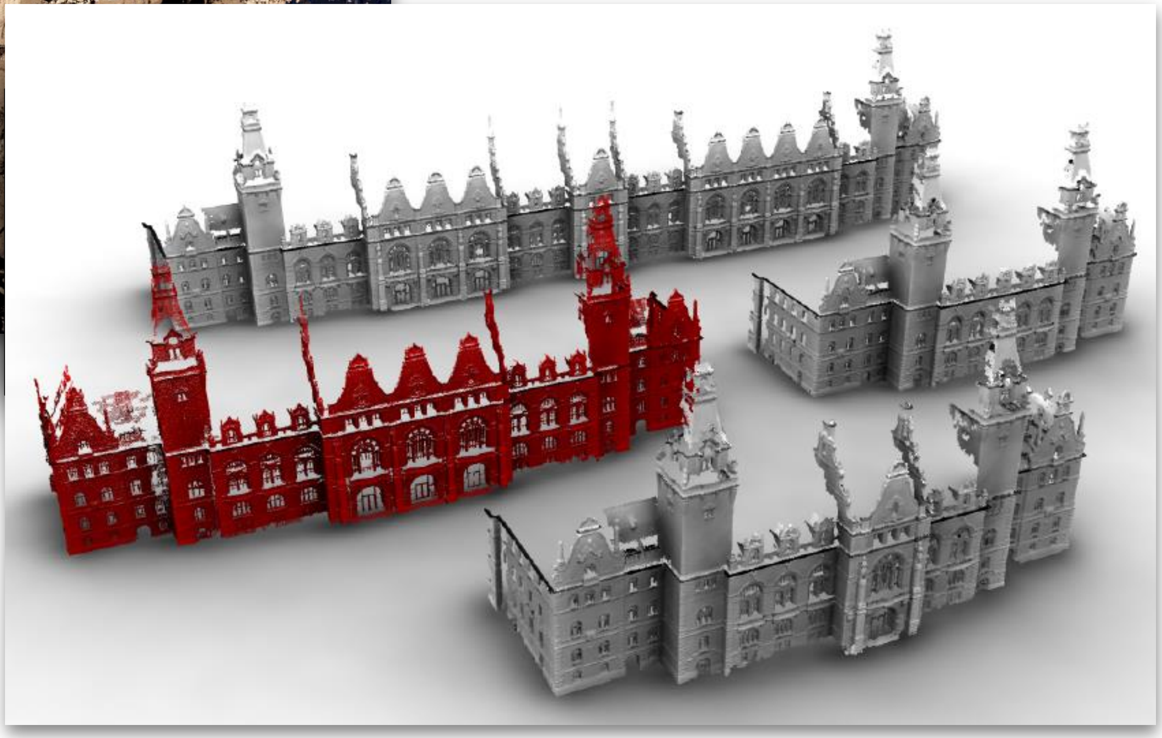


[Ihrke et al., CCD 2012]

[Christopher Schwartz, Michael Weinmann, Roland Ruiters, and Reinhard Klein, Bonn University]



[courtesy of Claus Brenner,
IKG Hannover]



[Michael Wand, Martin Bokeloh, Siggraph 2010]

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

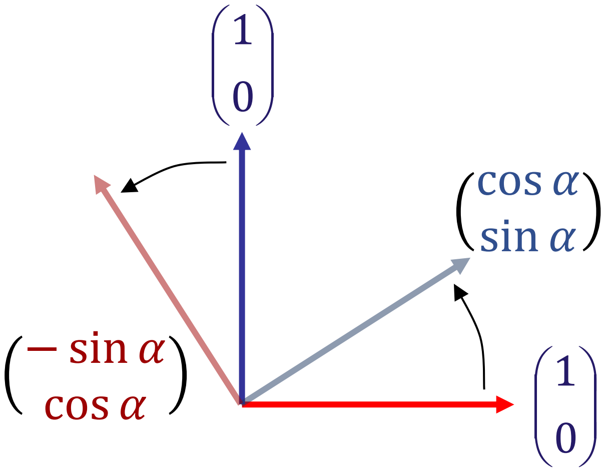
Prof. Dr. Tino Weinkauf

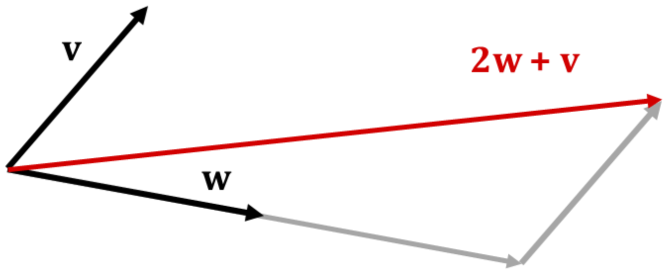
Introduction to Visualization and Computer Graphics

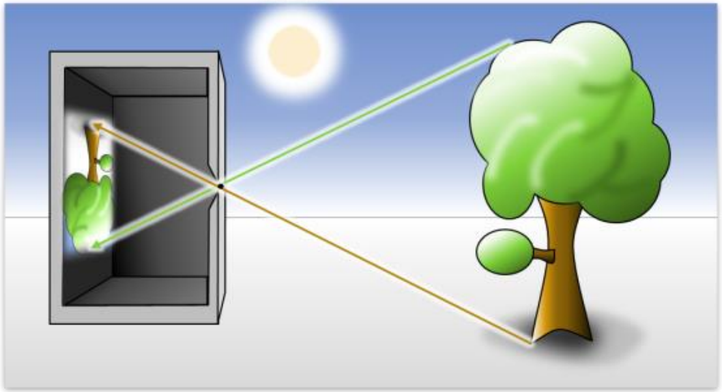
Overview of the Lectures
(tentative schedule)

- Linear transformations and homogeneous coordinates
- Spatial data structures and grids
- Modeling meshes
- Interpolation in 2D and 3D grids
- Shading and color
  - color models and perception
- Rendering: rasterization (projection, clipping, visibility)
- Rendering: raytracing
- Raycasting a volume
- All-purpose visualization methods and their best practices

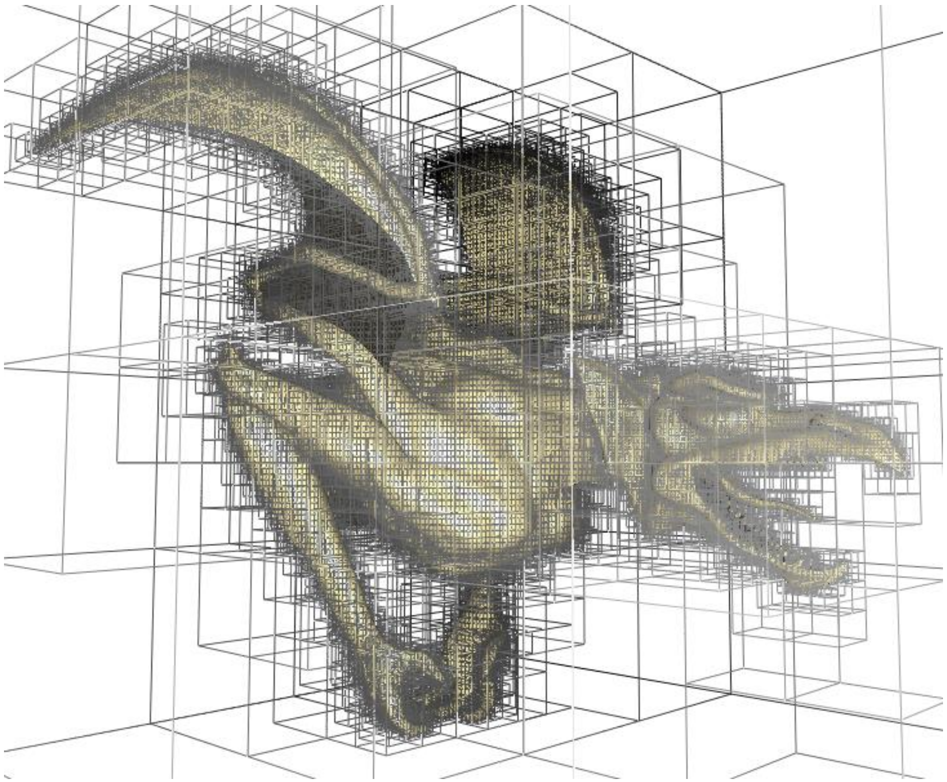
- Mathematics
  - Linear algebra
    - vectors / points
    - linear maps / matrices
  - Projective geometry
    - Homogeneous coordinates
    - Perspective transformations



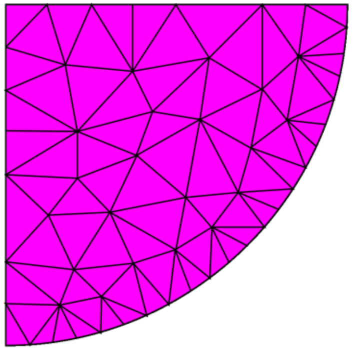


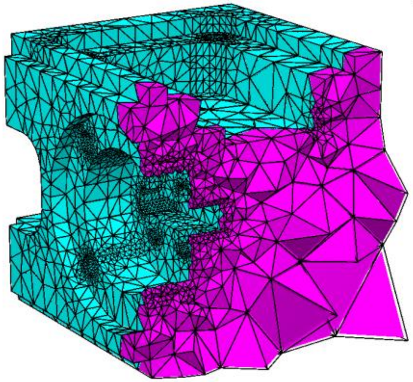


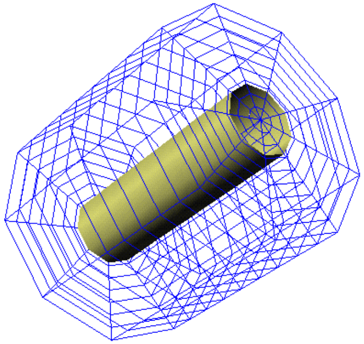
- Spatial data structures and grids
  - Quadtree / Octree
  - Bounding Volume Hierarchy
  - Structured grids (uniform, rectilinear, curvilinear)
  - Unstructured grids (triangle meshes, tetrahedral meshes)



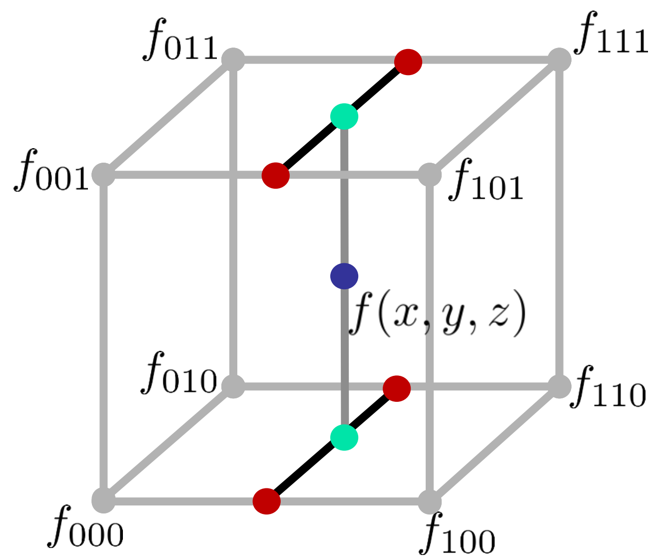
http://www.math.ucsb.edu/~chohong/vortex_in_a_box.jpg

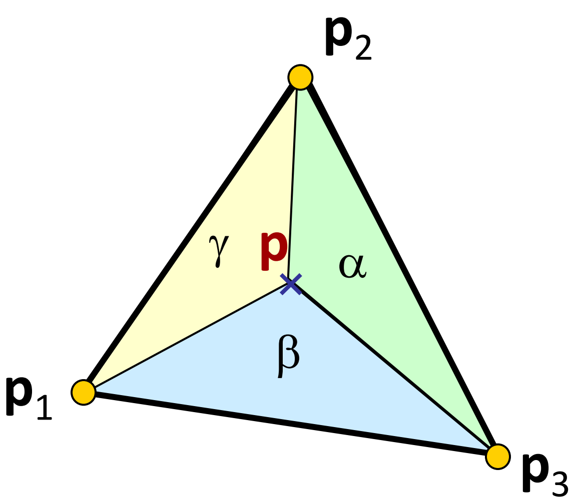


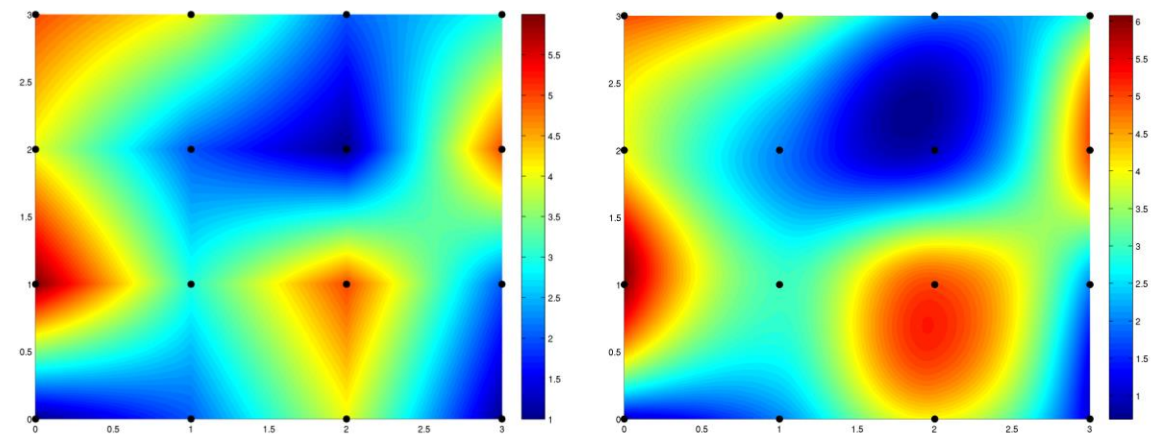




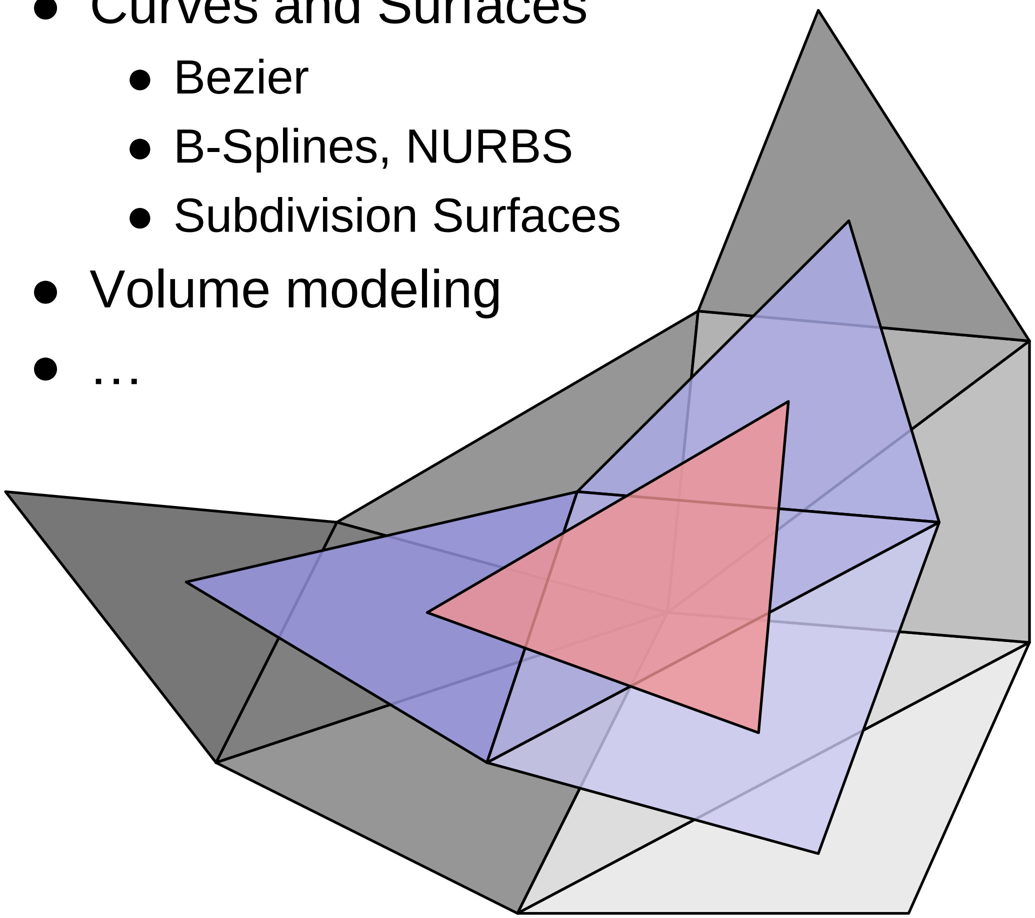
- Interpolation
  - Linear interpolation
  - Bilinear interpolation
  - Trilinear interpolation
  - Barycentric coordinates

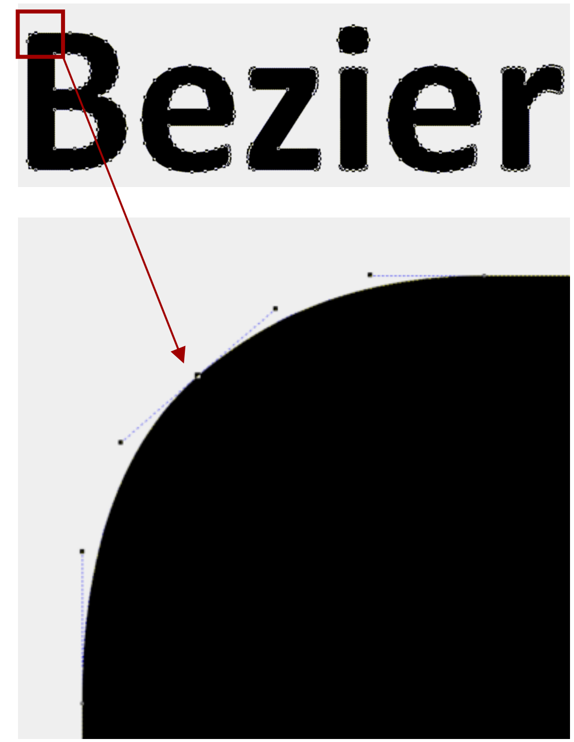


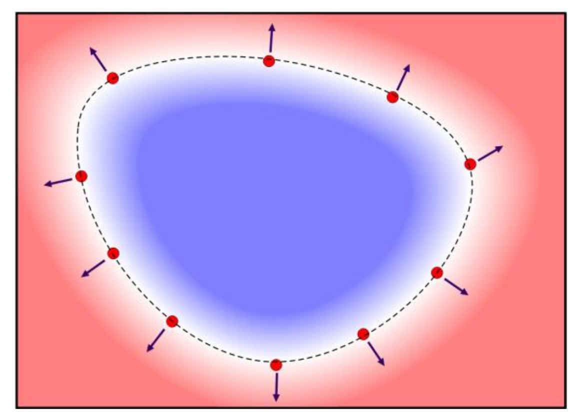




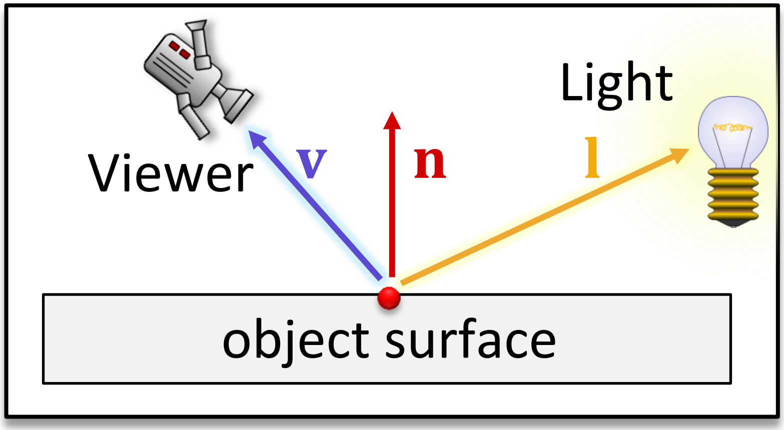
- Modeling
  - Overview of modeling methods
  - Solid models
  - Curves and Surfaces
    - Bezier
    - B-Splines, NURBS
    - Subdivision Surfaces
  - Volume modeling
  - …

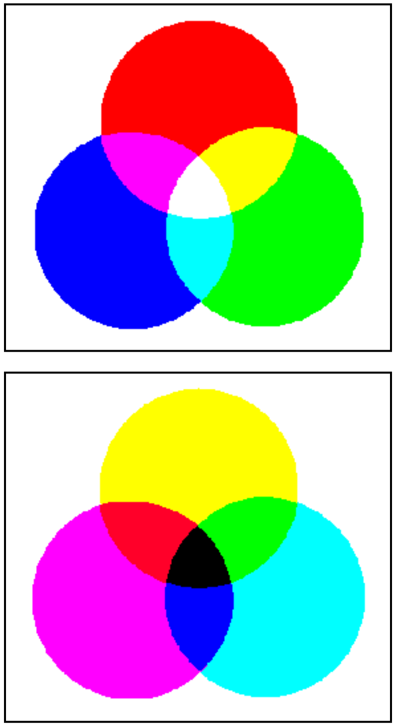


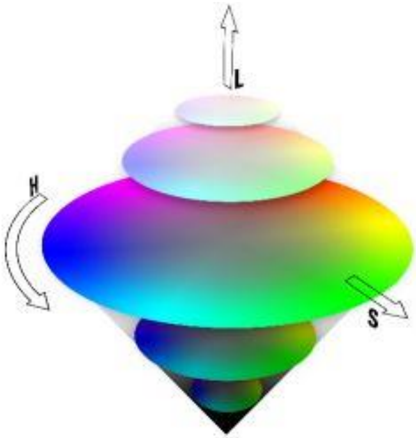


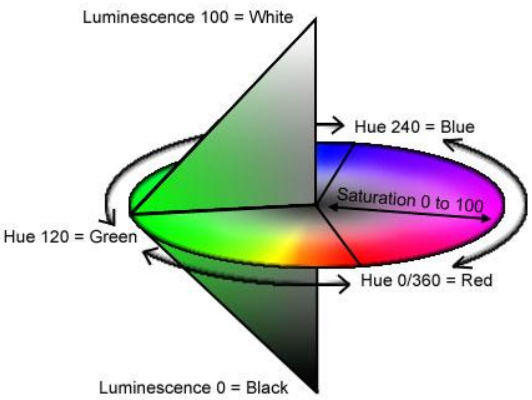


- Shading and Color
  - Phong illumination model
  - Color models
  - Color perception

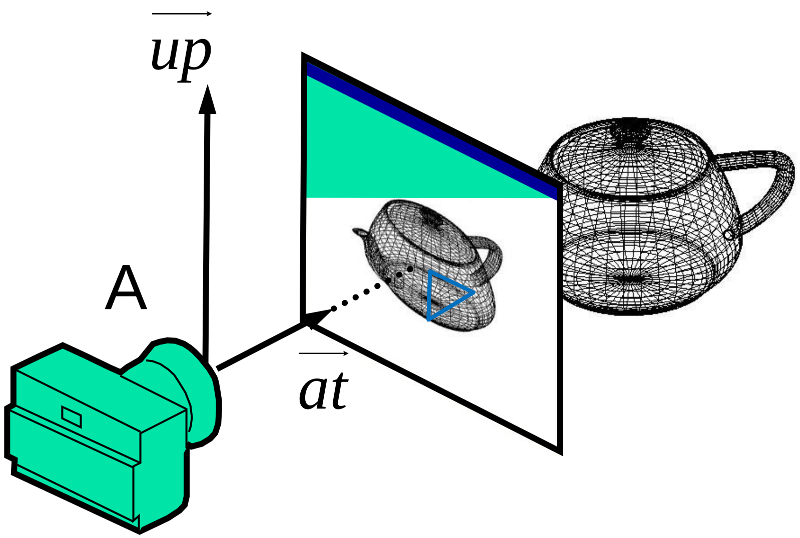


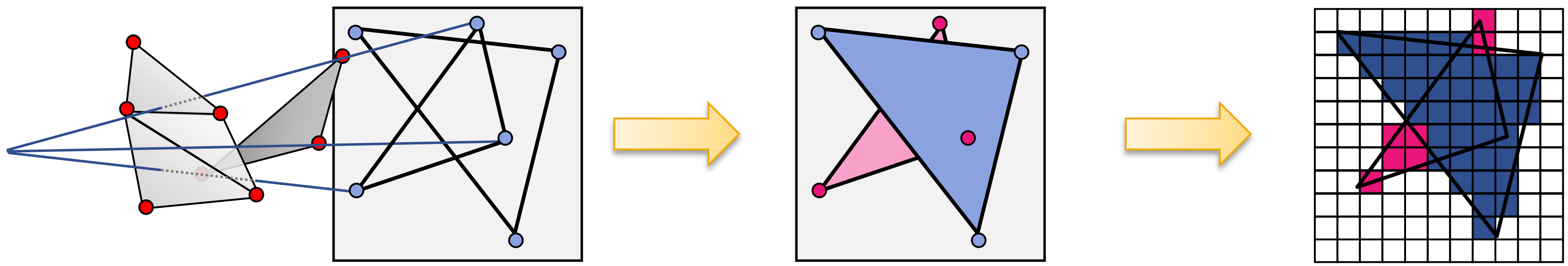




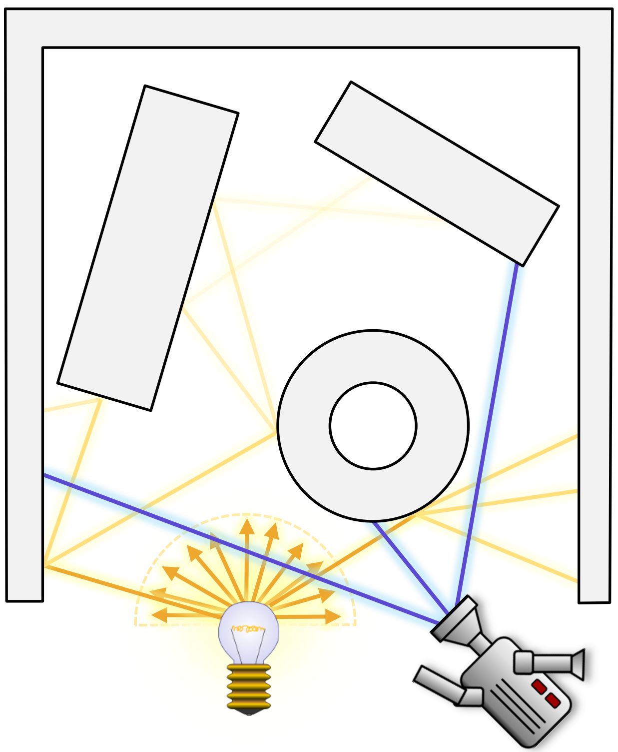


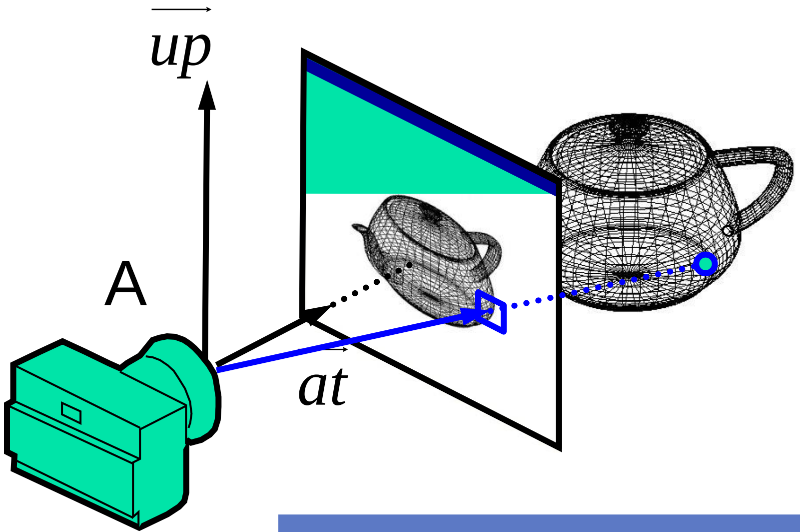
- Rasterization
  - Projection
  - Clipping
  - Visibility

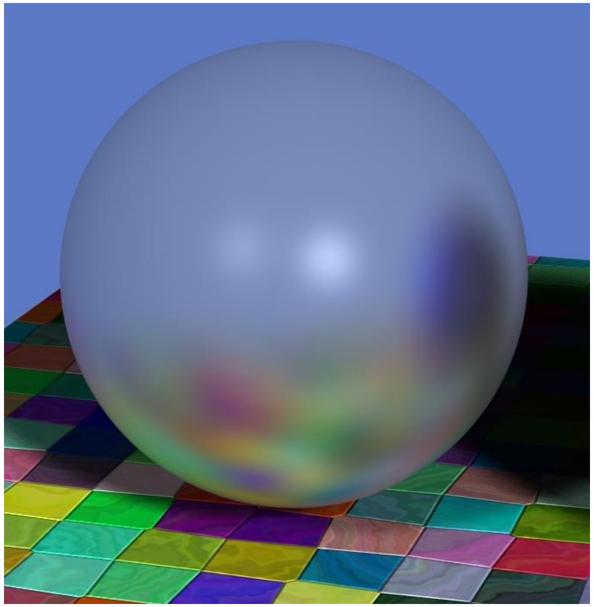




- Raytracing

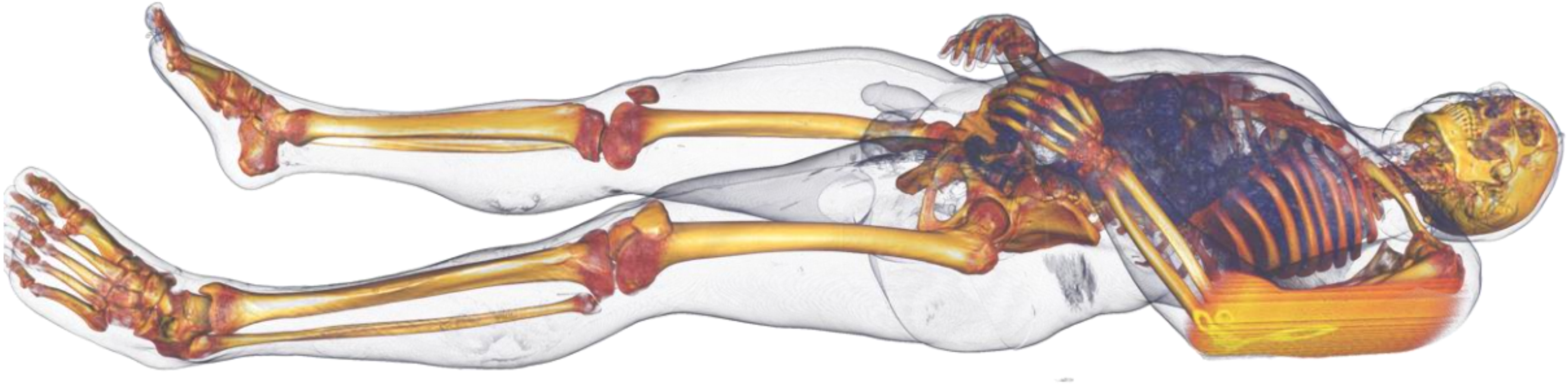






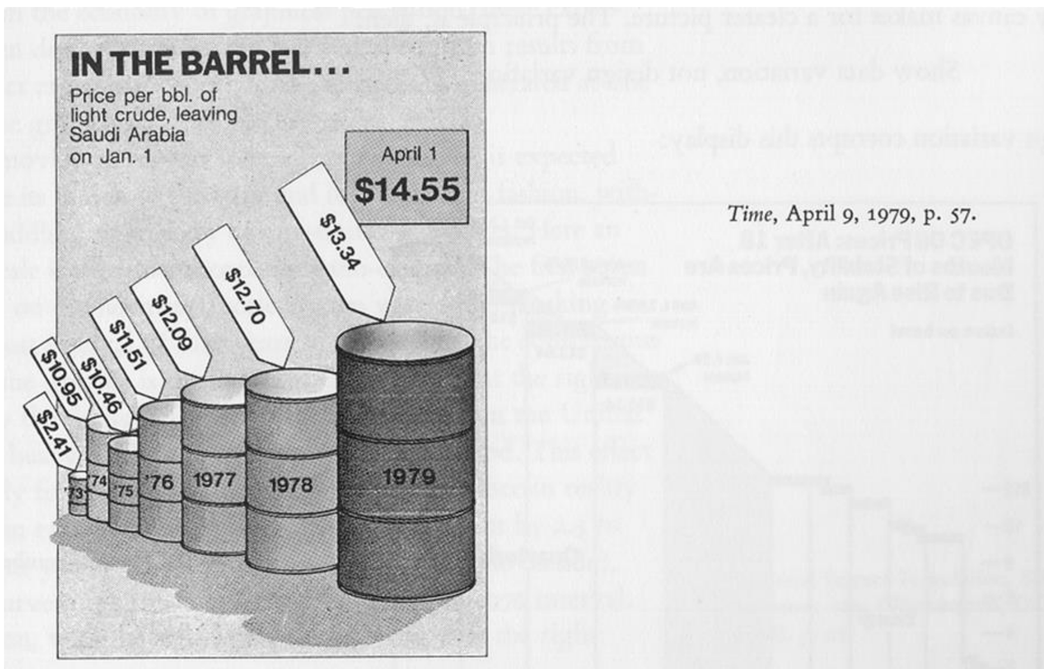
Justin Legakis

- Raycasting
  - Visualization method for 3D scalar fields
  - Main applications in life sciences (medicine, biology, …)



- All-purpose visualization methods & best practices
  - Line plots, Bar plots, Histograms
  - How not to lie with visualization

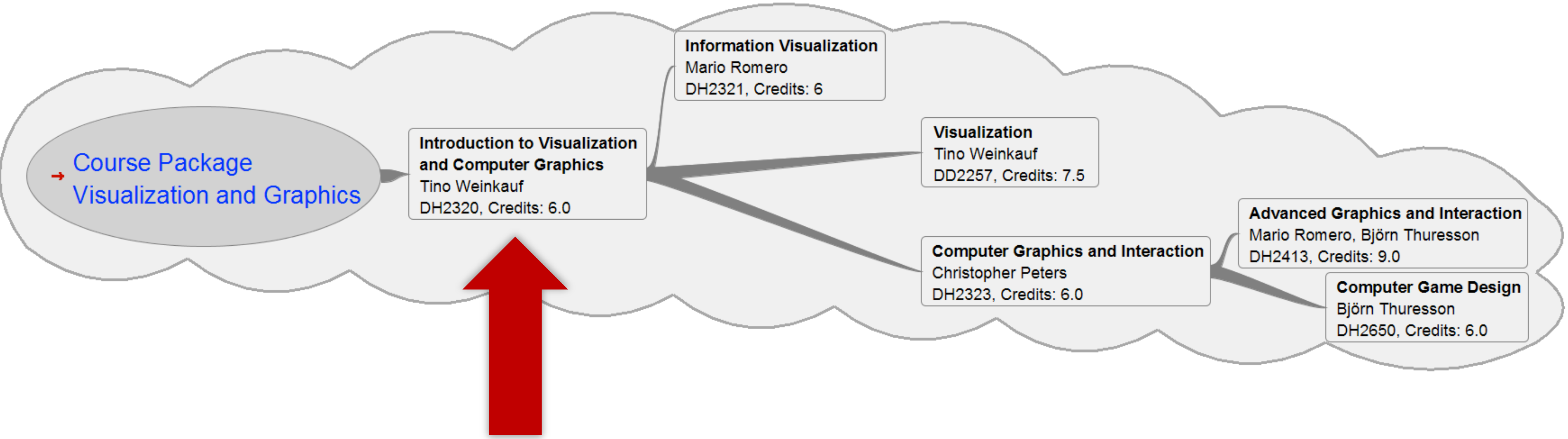
- Exam preparation
  - You ask about the content of the lecture, i.e., clarifications.



Prof. Dr. Tino Weinkauf

Introduction to Visualization and Computer Graphics

Overview of follow-up courses


Course Package
Visualization and Graphics
Introduction to Visualization and Computer Graphics
Tino Weinkauf
DH2320, Credits: 6.0
Information Visualization
Mario Romero
DH2321, Credits: 6
Visualization
Tino Weinkauf
DD2257, Credits: 7.5
Computer Graphics and Interaction
Christopher Peters
DH2323, Credits: 6.0
Advanced Graphics and Interaction
Mario Romero, Björn Thuresson
DH2413, Credits: 9.0
Computer Game Design
Björn Thuresson
DH2650, Credits: 6.0