

Computer Graphics

Contents

- Computer graphics: what and why
- Many scenes, two rendering paradigms and one image
- Course organization

Computer graphics: what and why

Motivation

"Inspired by nature, incorporate science and art with technology to create virtual environments that exist or never could have existed."

"Computer graphics is science and art of communicating visually via computer display and its interaction devices" *

"A collaboration between art and technology" **

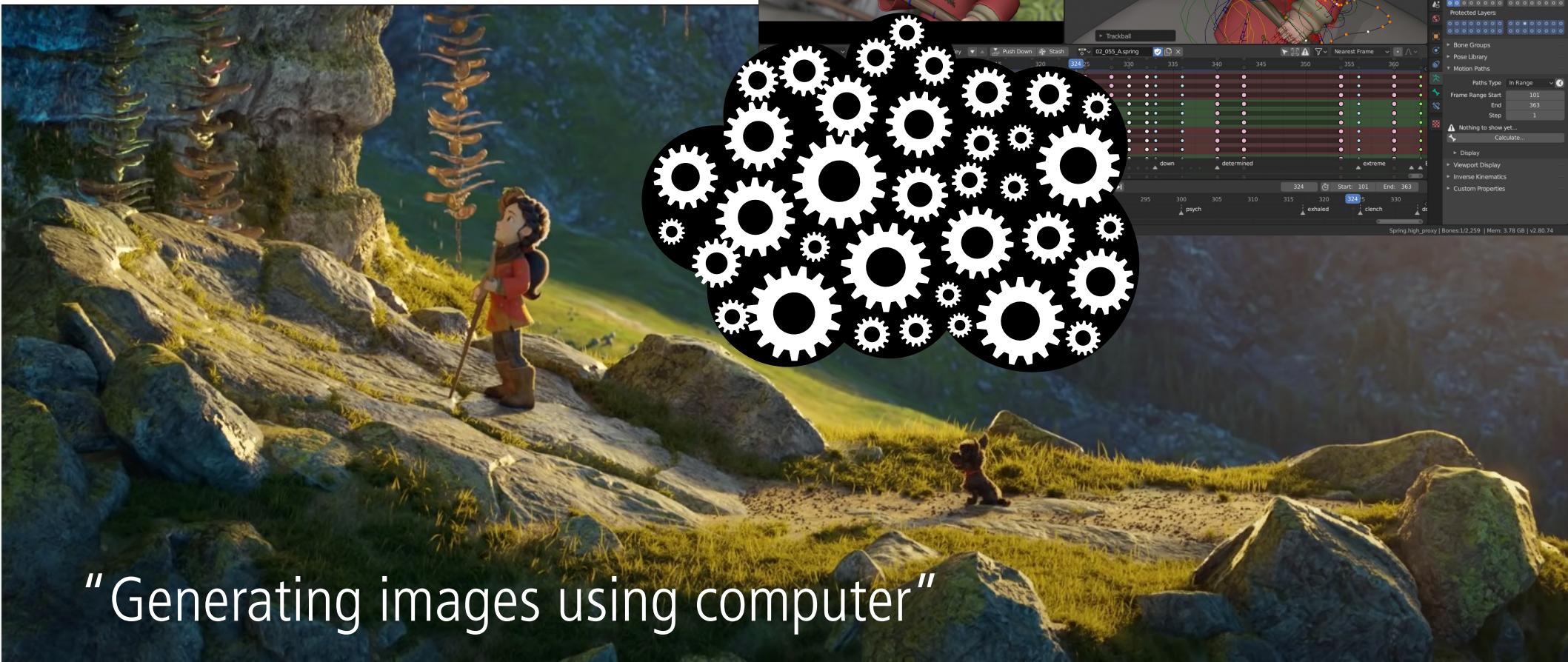
To visualize

To express

* Book: principles and practices

** Pixar

Computer graphics

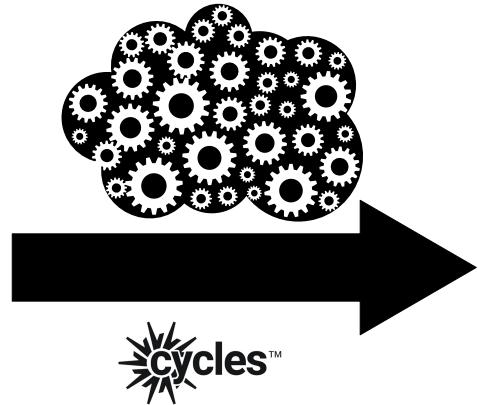
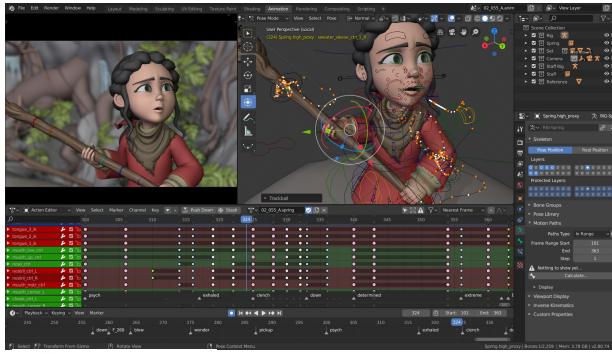


"Generating images using computer"

Computer graphics

Generating images:

- **3D scene** – what will be present in image
- **Rendering** – how image is generated from 3D scene
- **Image display** – how image is displayed



Computer graphics and you

- You like **physics** and would like to see its practical applications in generating amazing imagery and effects.
- You like **mathematics**: computer graphics is applied mathematics. Enough said.
- You like **programming**: computer graphics is exciting application that employs complex architectures for modeling and rendering and in return gives very gratifying results.
- You like **art and design**: Computer graphics is not only about tools which serve for simulating and rendering 3D scenes - it is also how we use those tools to create something that exists or never existed
- You like **animated films** or **VFX**: yes there is a lot of computer graphics there combined with other disciplines to support stories to remember
- You like **computer games**: amazing application of computer graphics combined with different disciplines
- You like **visualization**: biology? Chemistry? Geology? Astronomy? Computer graphics is there for you!

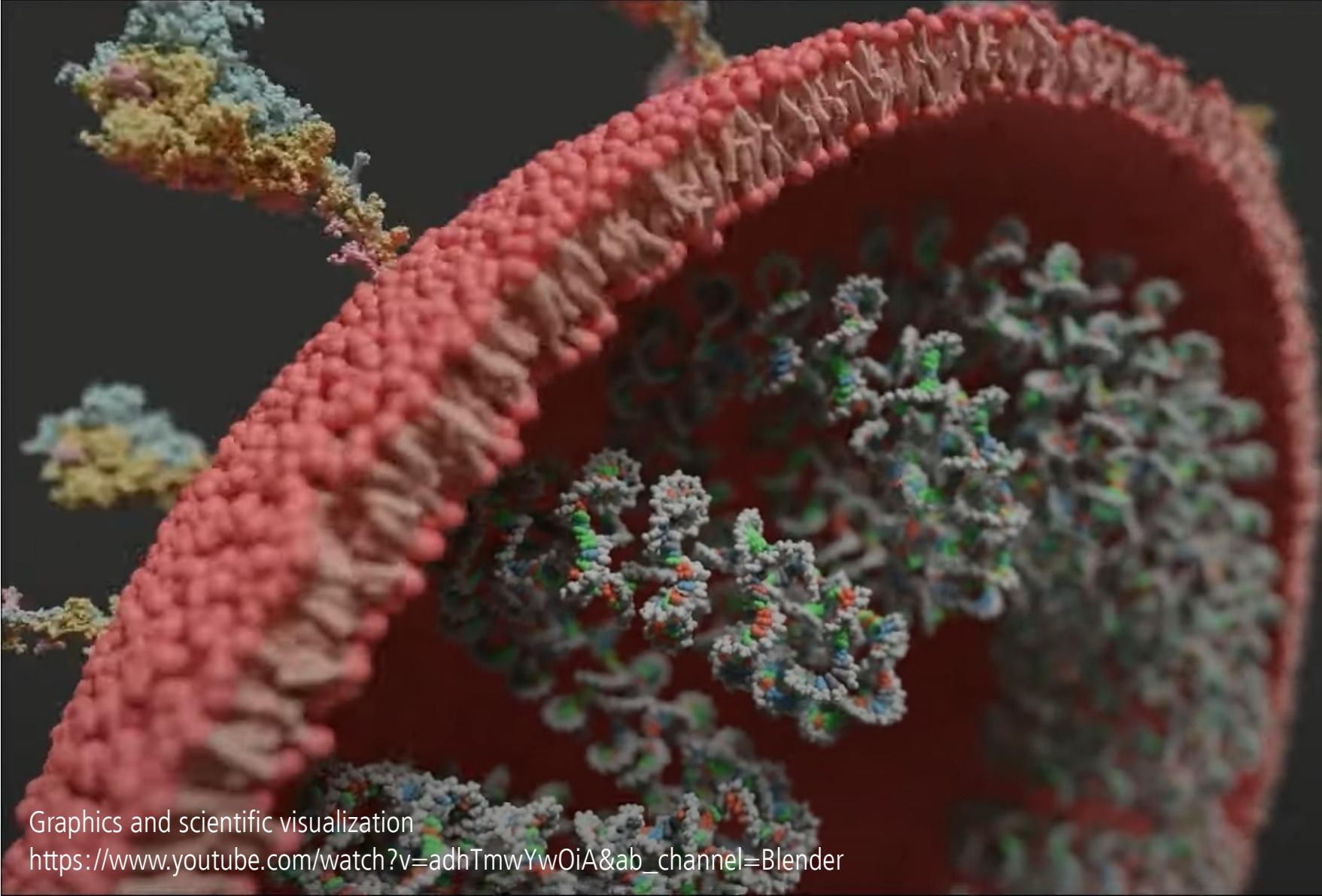


Graphics and computer games

<https://www.rockstargames.com/reddeadredemption2/>

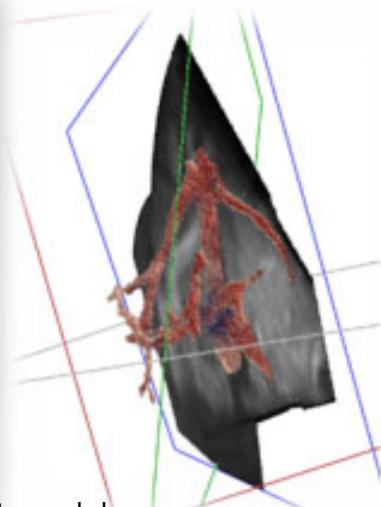
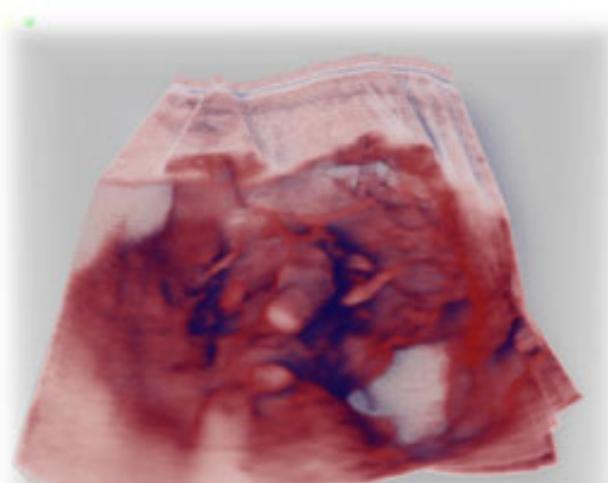
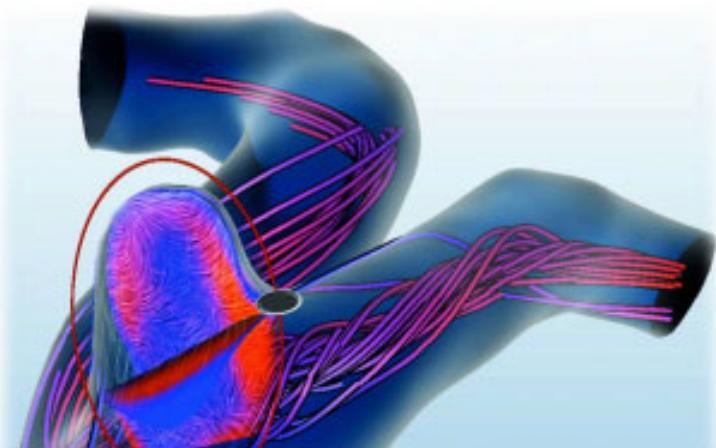
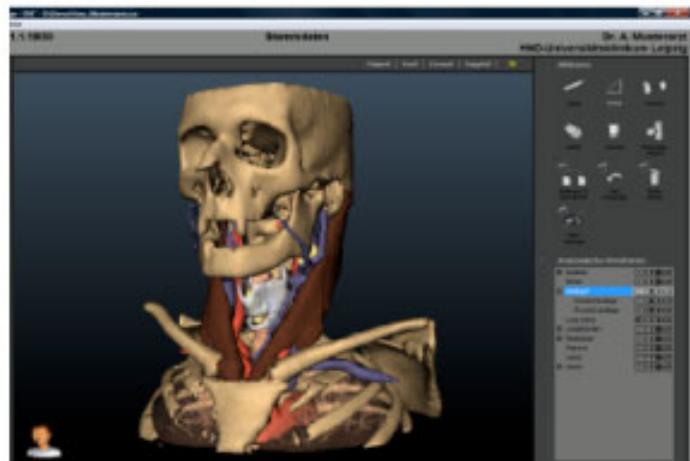
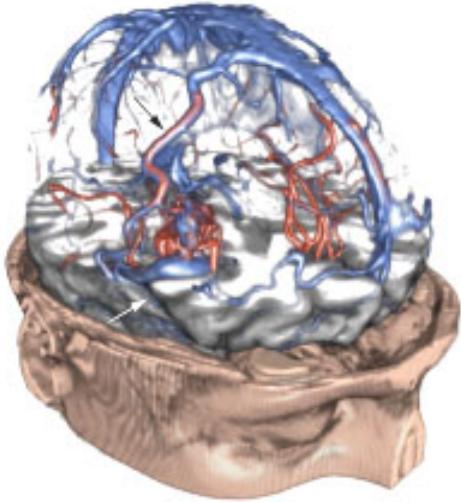


Graphics and animated film
<https://www.pixar.com/soul>



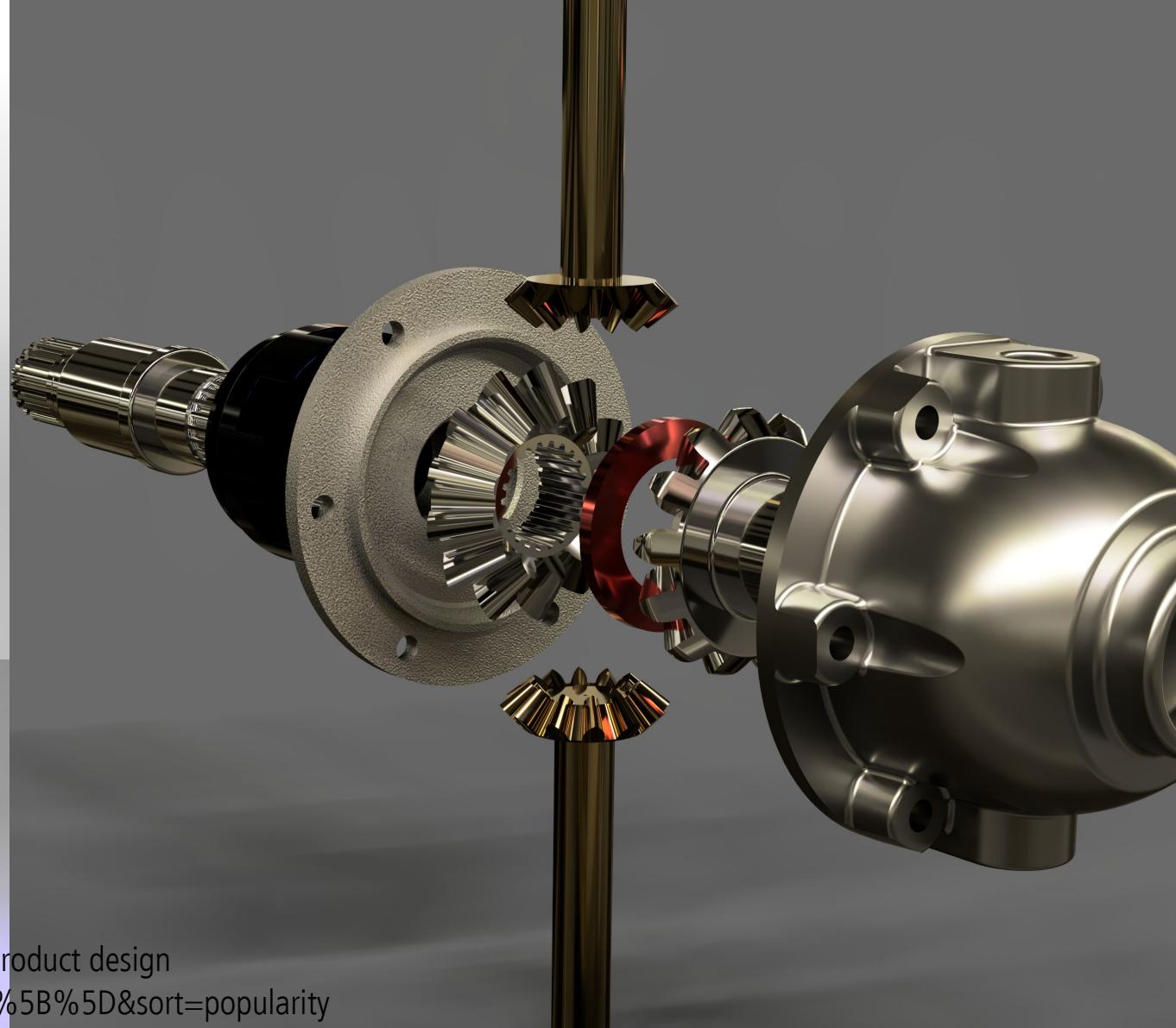
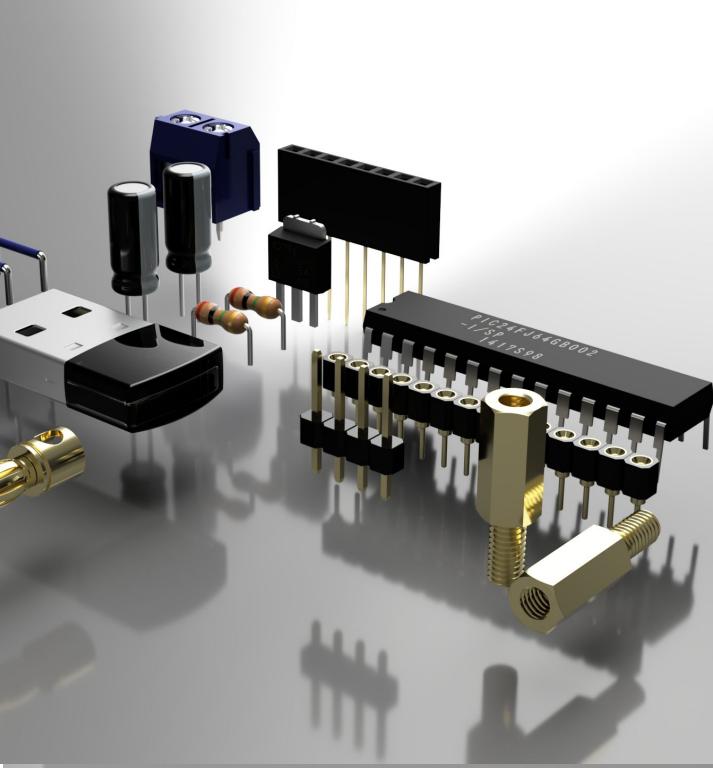
Graphics and scientific visualization

https://www.youtube.com/watch?v=adhTmwYwOjA&ab_channel=Blender

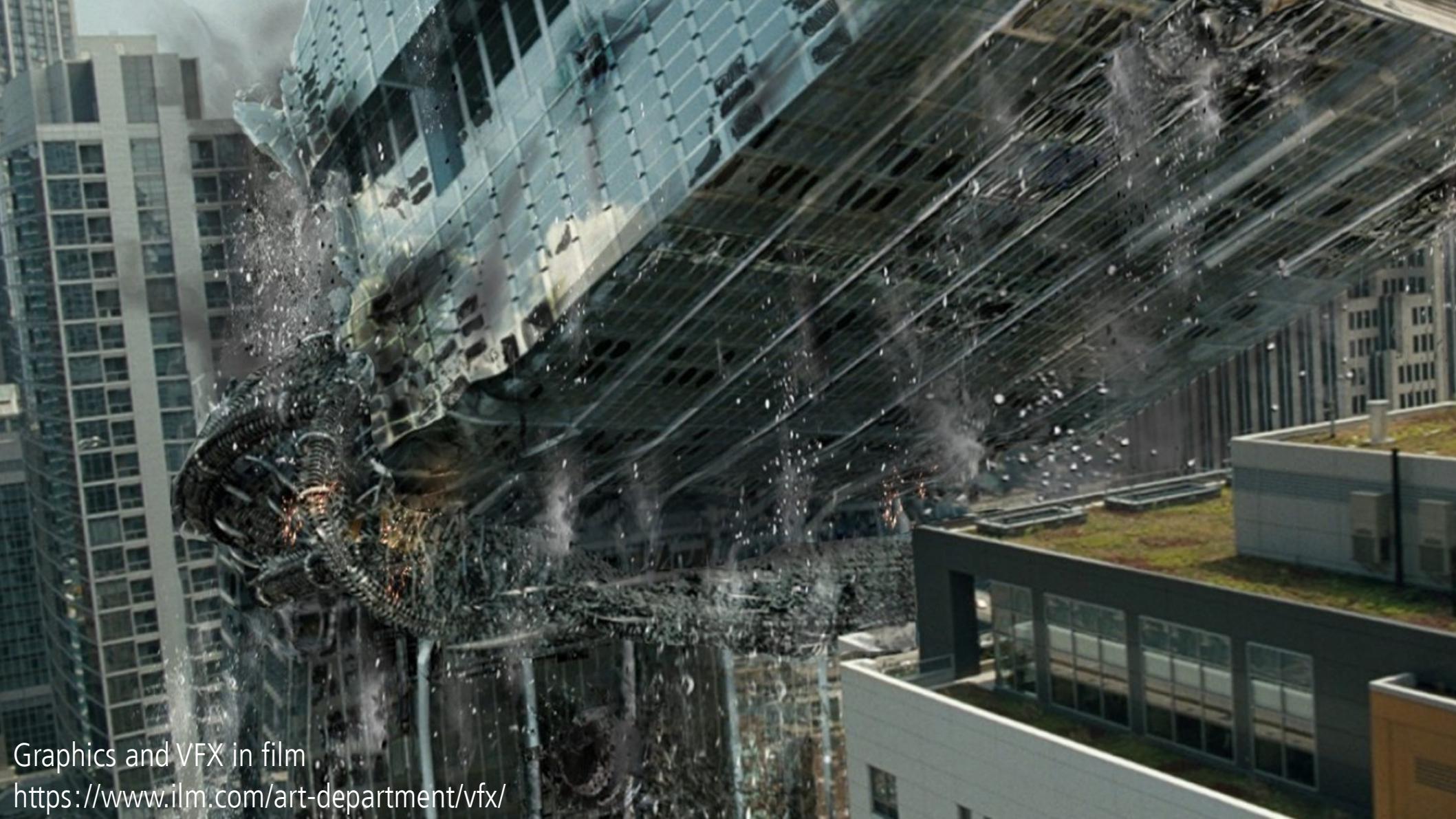


Graphics and medicine

<https://www.siggraph.org/news/eurographics-celebrates-computer-graphics-in-medicine/>



Graphics and CAD, manufacturing, engineering, product design
<https://gallery.autodesk.com/projects/all#filters=%5B%5D&sort=popularity>



Graphics and VFX in film

<https://www.ilm.com/art-department/vfx/>



Graphics and simulation for VFX in film

https://www.youtube.com/watch?v=lS--1gRjfRk&ab_channel=Rebelway



Graphics and motion capture for VFX in film

<https://www.fxguide.com/fxfeatured/weta-digital-s-remarkable-face-pipeline-alita-battle-angel/>

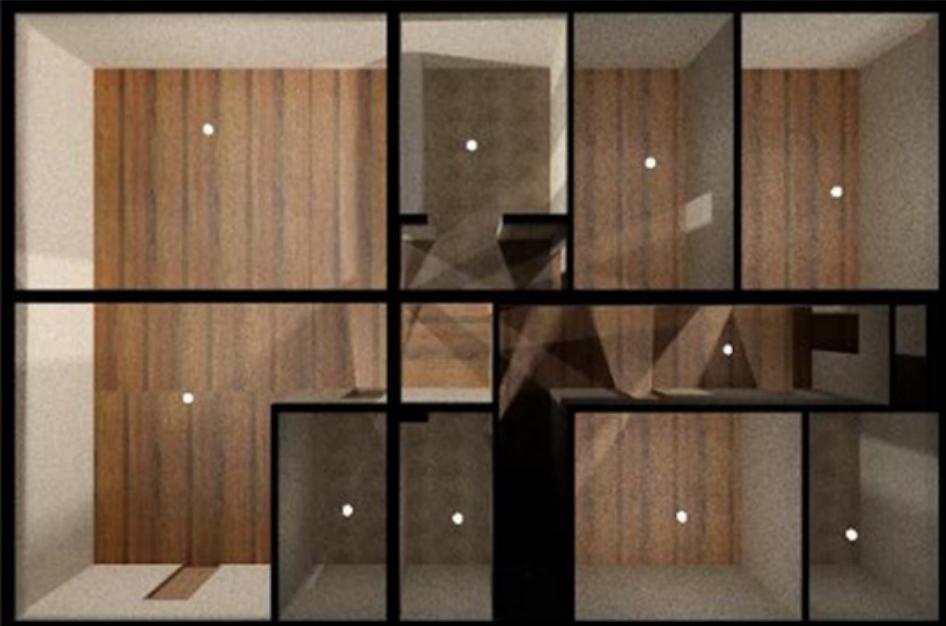


Graphics and arhitecture

<https://www.blenderguru.com/articles/20-jaw-dropping-architectural-renders>



Graphics and interior design; ergonomic design
<https://www.blenderguru.com/articles/20-jaw-dropping-architectural-renders>

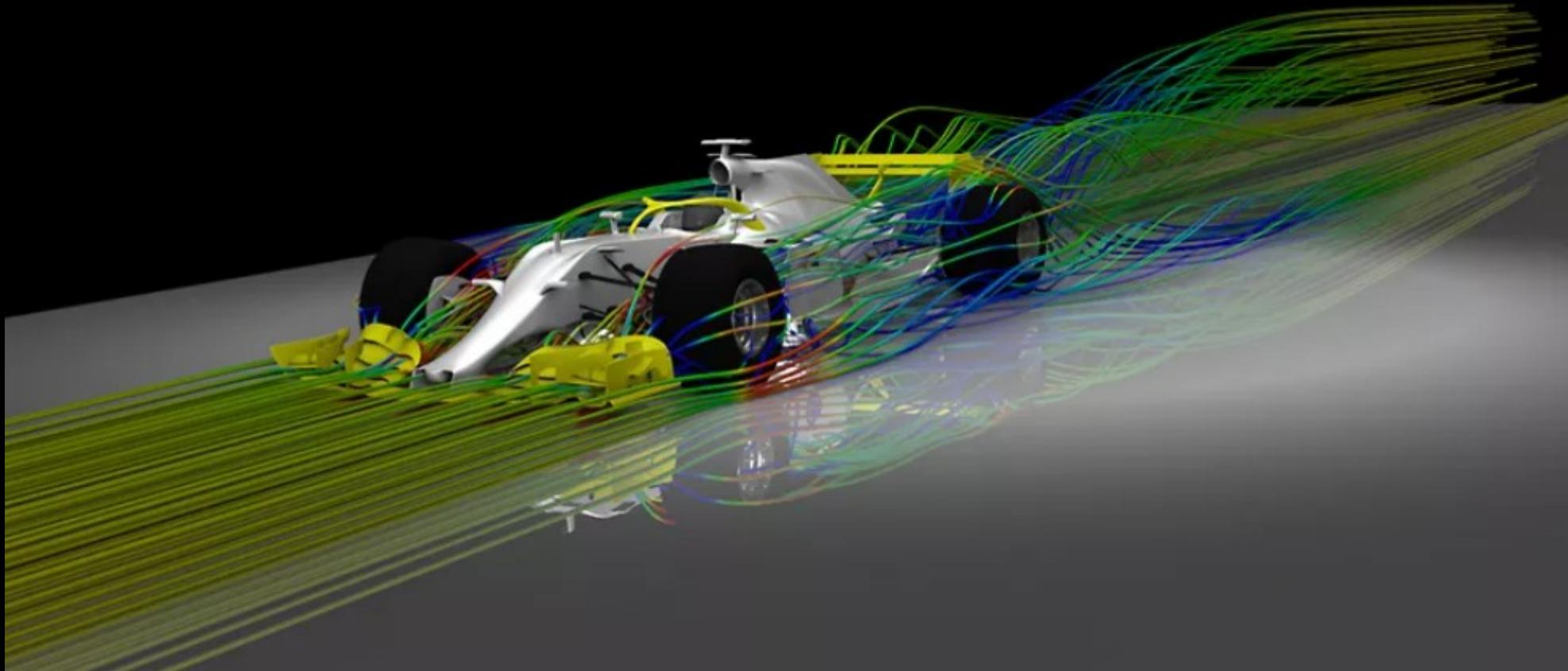


graphics and illumination planning
http://graphics.cs.aueb.gr/graphics/research_lightingopt.html



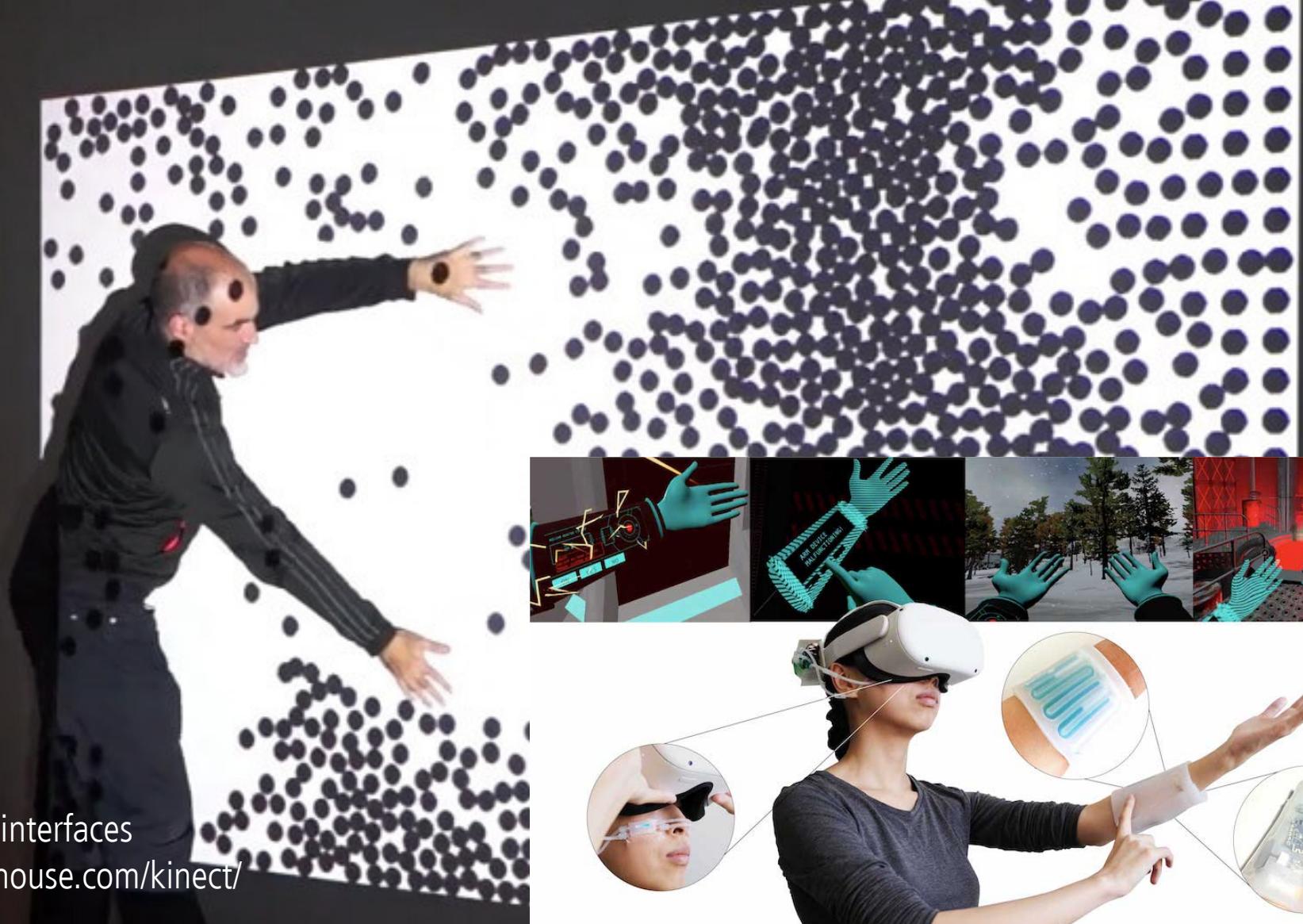


Graphics and new media art
<https://refikanadol.com/>



Graphics and predictive simulations

<https://www.ansys.com/company-information/the-ansys-story>



Graphics and user interfaces
<https://parametrichouse.com/kinect/>
<http://plopes.org/>

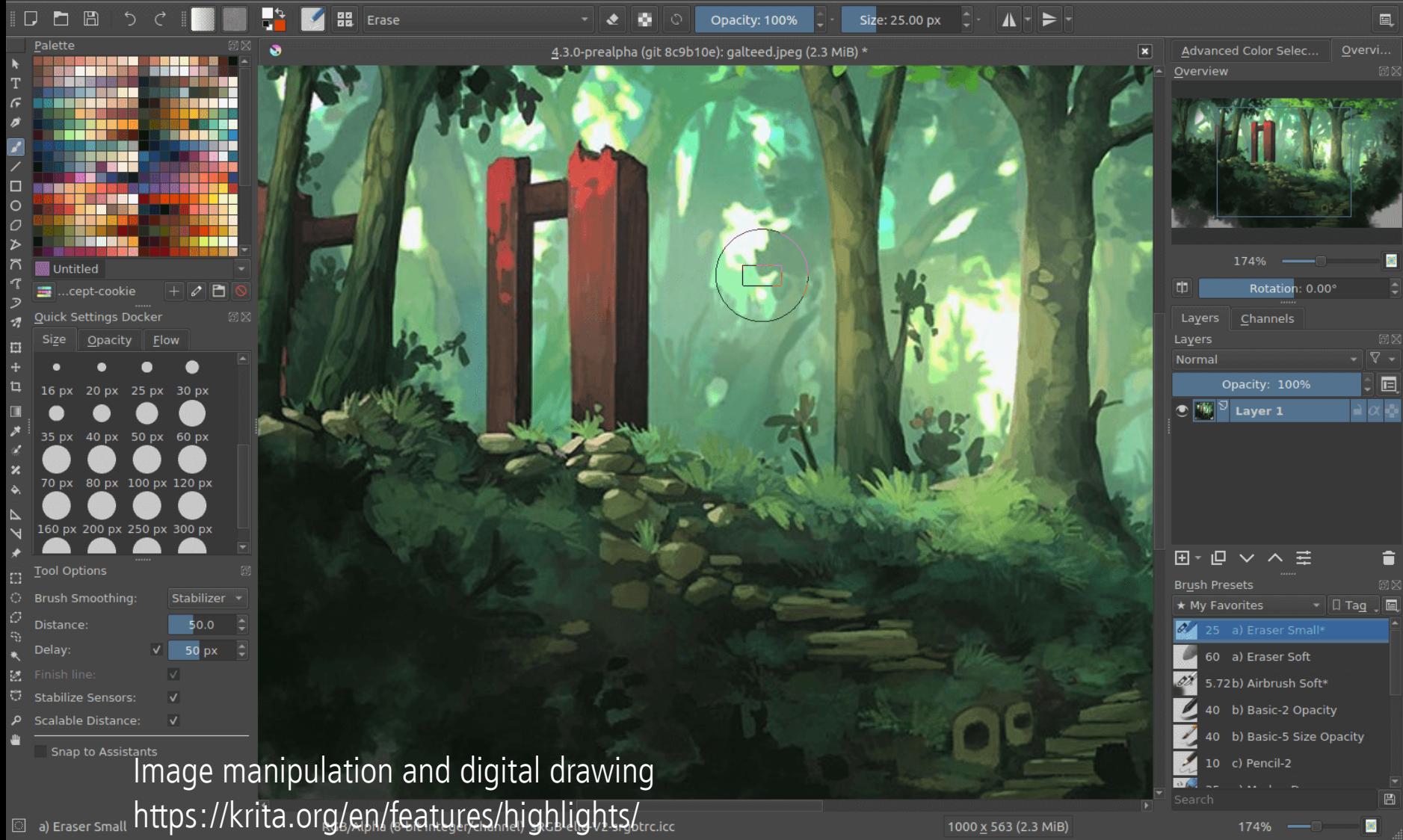
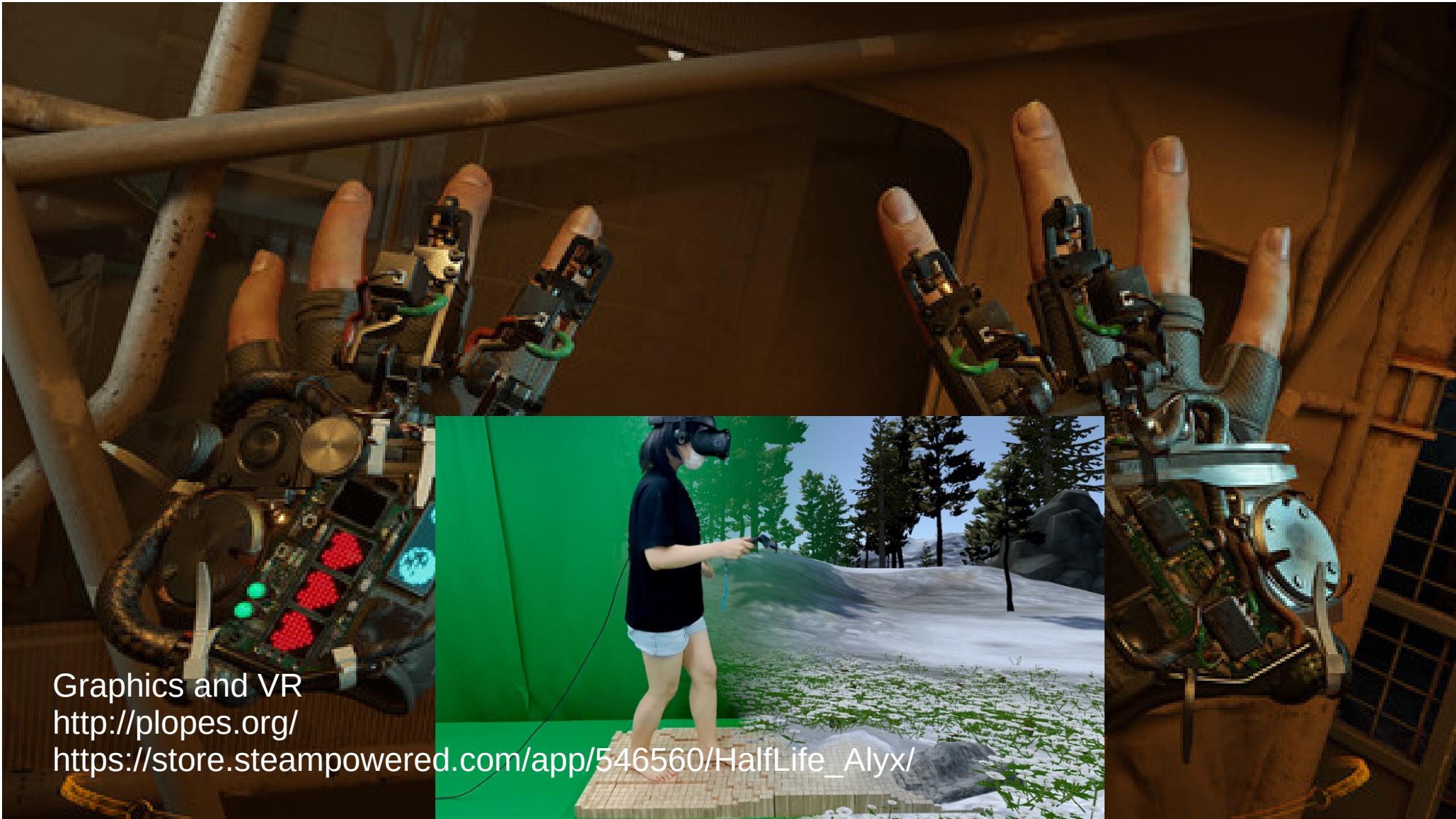


Image manipulation and digital drawing
<https://krita.org/en/features/highlights/>



Graphics and VR
<http://plopes.org/>
https://store.steampowered.com/app/546560/HalfLife_Alyx/

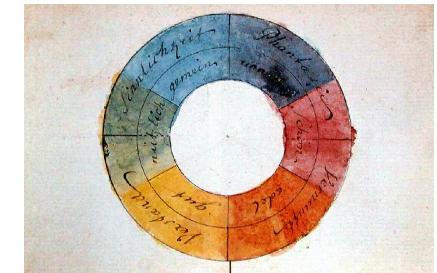
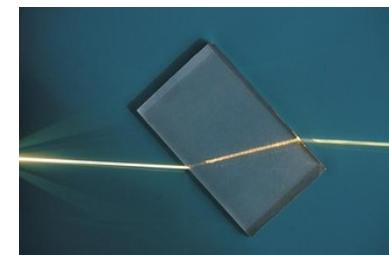
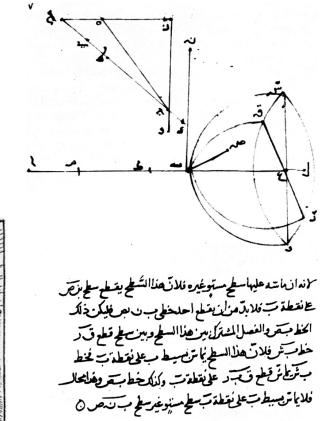
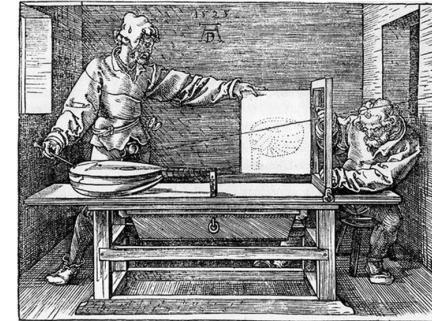


Computer graphics and AR

<https://deltareality.com/portfolio/vaillant-ar-facility-tour/>

Bit of history

- Geometric optics (Alhazen (Ibn al-Haytham), "the father of Optics", 1010)
- Development of perspective projection in drawing: perspective machine (e.g., Albrecht Dürer, 1525)
- Development in optics (Physics, e.g. Young, 1807)
- Johann Wolfgang von Goethe and Theory of Colors, 1810
- Geometry, linear algebra, statistics

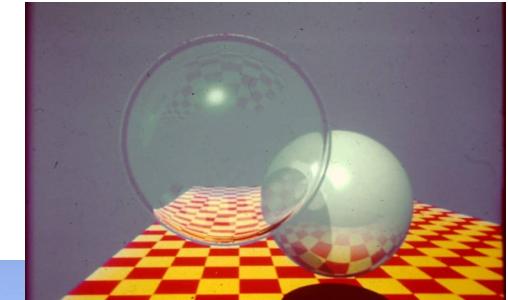


Bit of history

- Computer science and hardware (IBM 2250, 1964)
- VFX (ILM, 1975)
- Ray-tracing (J. Turner Whitted, 1979)
- Animated films (Pixar, 1986)
- Games (Naughty dog, 2013)



INDUSTRIAL
LIGHT & MAGIC



Computer graphics today



<https://www.siggraph.org/>



<https://research.nvidia.com/research-area/real-time-rendering>



<https://www.research.autodesk.com/blog/inside-autodesk-research-explore-our-research-teams/#industry-futures>

Many scenes, two renderers and one image

Glimpse into image generation

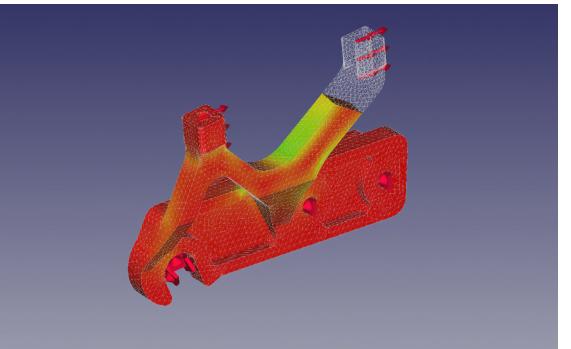
Analogy: taking a photograph

- World surrounding photographer → **3D scene**
- Light interaction with world and image formation → **rendering**
- Result: **Image**



3D scene creation

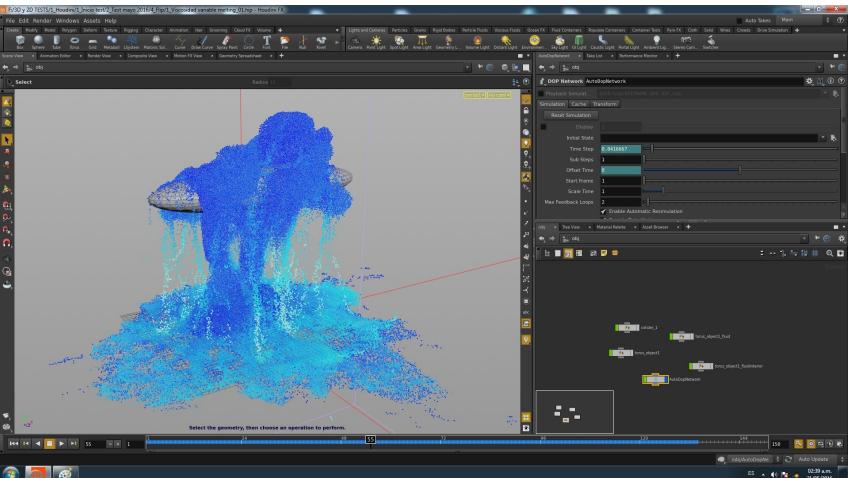
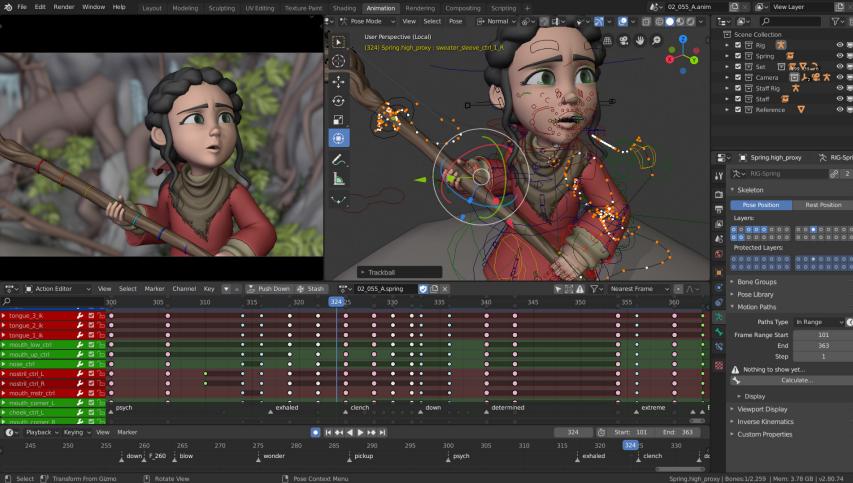
- Modeling: artists, engineers, designers, etc.
 - CAD modeling, sculpting
 - Animation
 - Simulation
- Acquisition from real world
 - Scanning



<https://www.freecadweb.org/>

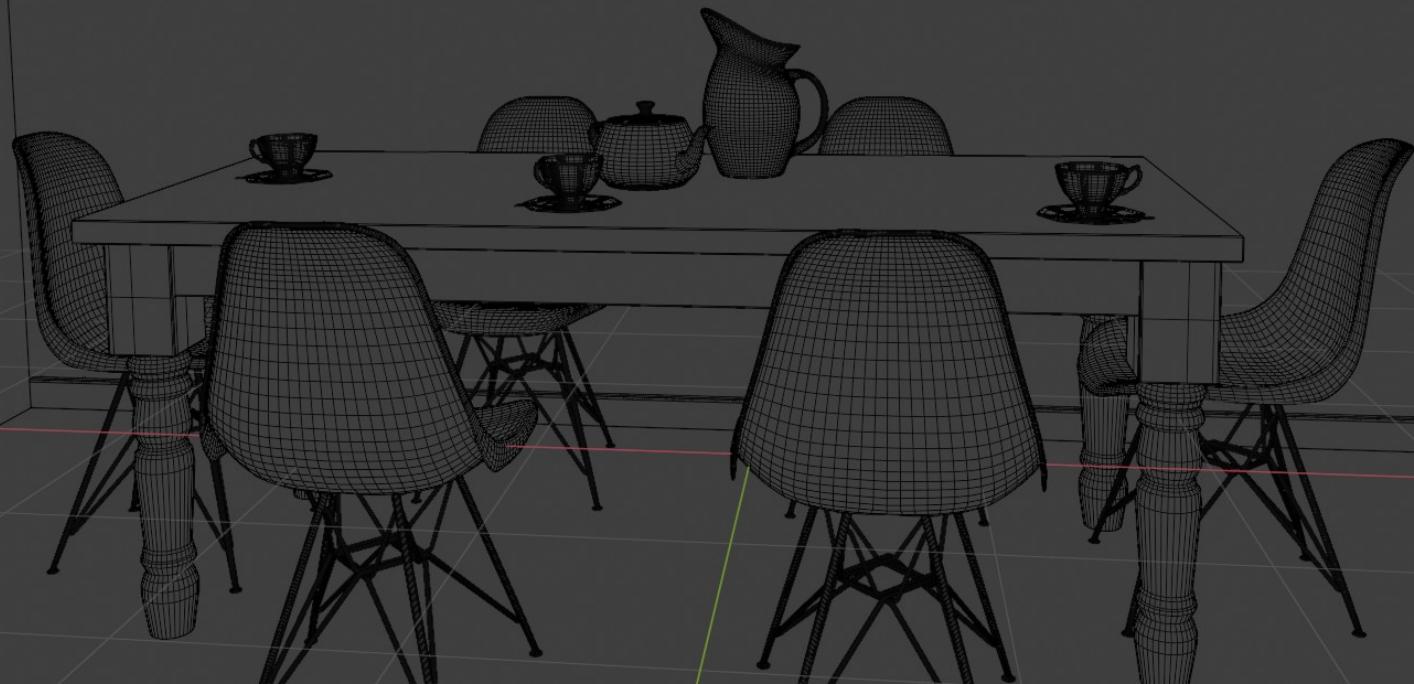


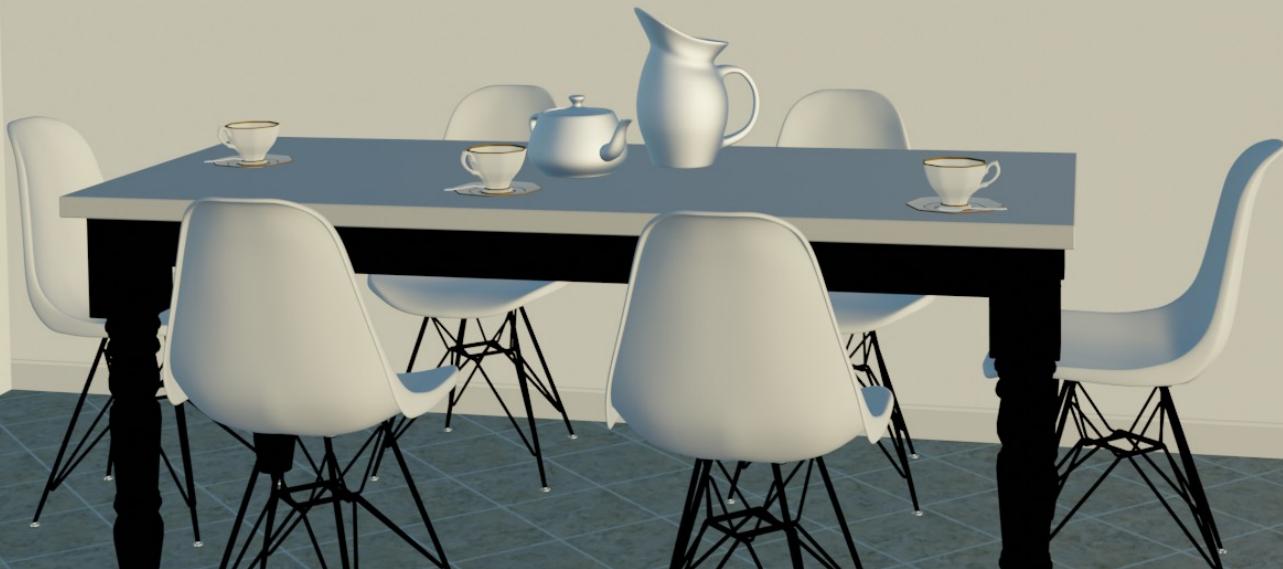
<https://alicevision.org/>



<https://e7p.artstation.com/projects/XbPLD>

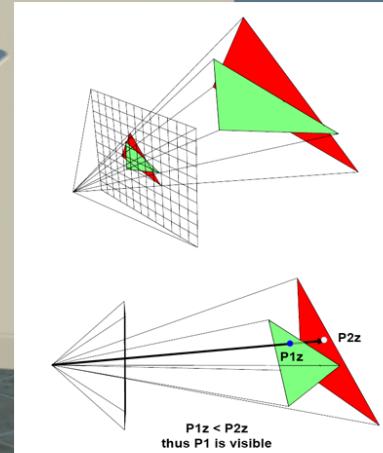
3D scene





A dining room scene featuring a long, rectangular table set for tea. On the table, there is a white teapot, a small white pitcher, and four blue and white teacups arranged on saucers. The table is surrounded by several chairs with black frames and light-colored, curved backrests. Two pendant lights with orange domes hang over the table, casting a warm glow. The background shows a wall with horizontal window blinds, through which sunlight streams in, creating sharp, diagonal shadows across the room.

Rendering: rasterization-based rendering



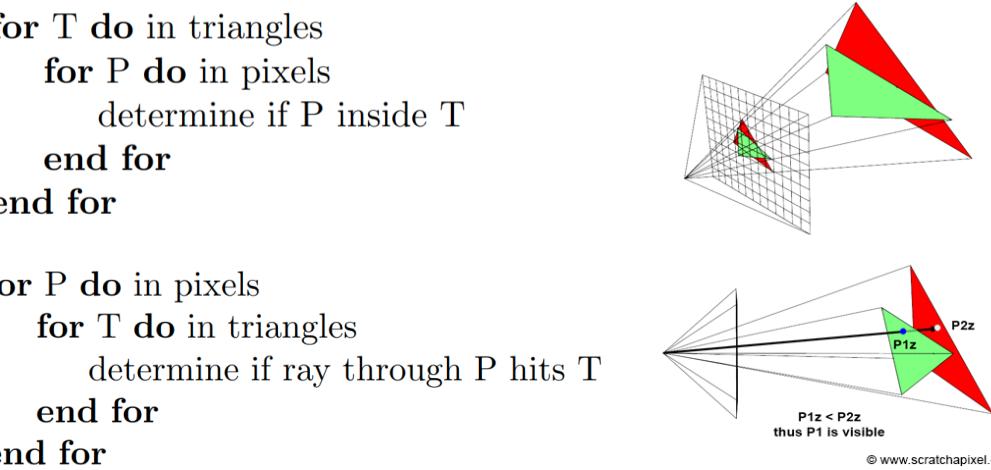
Rendering

- Rasterization-based rendering
- Ray-tracing based rendering



```
for T do in triangles  
  for P do in pixels  
    determine if P inside T  
  end for  
end for
```

```
for P do in pixels  
  for T do in triangles  
    determine if ray through P hits T  
  end for  
end for
```



Rendering

- Rasterization-based rendering: interactivity
- Ray-tracing based rendering: fidelity



<https://www.starwars.com/lego-star-wars-the-skywalker-saga>



Image



Different exposures of the same render: https://docs.blender.org/manual/en/latest/render/color_management.html

Landscape of computer graphics

- <https://www.realtimerendering.com/portal.html>



Real-Time Rendering Portal

Last changed: September 28, 2022

This page is devoted to sites and tools we use on a continuing basis. They're personal picks, and reflect our own biases.

1. [Ke-Sen Huang's conference pages](#) has links for papers from all the major computer graphics conferences and workshops. The pages by Tim Rowley are not available directly, but [this archive](#) contains them.
2. [Advances in Real-Time Rendering in 3D Graphics and Games](#), [Introduction to Real-Time Ray Tracing](#), [Open Problems in Real-Time Rendering](#), [An Overview of Next-Generation Graphics APIs](#), and [Stylized Rendering in Games](#) SIGGRAPH course materials are hosted on our site.
3. [SIGGRAPH 2021 links](#), compiled by Stephen Hill. Also see link pages for [SIGGRAPH 2020 links](#) [SIGGRAPH 2019 links](#) (and [SIGGRAPH 2019 ray tracing links](#)), [SIGGRAPH 2018](#), [SIGGRAPH 2017](#), [SIGGRAPH 2016](#), [SIGGRAPH 2015](#), [SIGGRAPH 2014](#), [SIGGRAPH 2013](#), [SIGGRAPH 2012](#) and [SIGGRAPH 2011](#).
4. [Game Developers Conference 2019 links](#), also [2018](#), [2017](#), [2016](#). There's none for 2015, but before then Javier "Jare" Arevalo collected [GDC 2014](#), [2013](#), and [2012](#) presentations. Also see the [GDC Vault](#).
5. [Graphics Programming weekly](#) - Jendrik Illner summarizes graphics blog articles. Think of it as your one-stop blog. He also has a nice [searchable collection](#).
6. [NVIDIA](#) (and [NVIDIA Research](#)), and [AMD](#) (plus [GPUOpen](#)) graphics developer sites - demos, code samples, white papers, etc. Other worthwhile code samples at [Humus-3D](#).
7. Min Chen's list of [Computer Graphics Forum](#) State-of-the-Art (STAR), survey, and review papers since 2010.
8. [The Journal of Computer Graphics Techniques](#) - open access (free to all) and many articles include code samples.
9. [Journal of Graphics Tools](#) (JGT) code repository.
10. [Graphics Gems Repository](#) - contains the source code for many graphics algorithms. Search the contents by [category](#), by [author](#), or by [book](#).
11. [Developer sites and mailing lists](#): [GameDev.net](#) is active, as is [OpenGL.org](#), [Ogre Forums](#), [GD Algorithms archives](#) dying out but searchable ([subscribe](#)), and [FlipCode](#) (old, closed, but some good things in the archives).
12. [Game company publication pages](#): alphabetically, and a few quite dated, but here goes. [Frostbite](#), [Guerrilla Games](#), [Unreal Engine](#), [Unity](#), [Ready At Dawn](#), [Tri-Ace](#), and [Activision](#).
13. [Film company publication pages](#): [Disney](#) ([Hyperion renderer specific](#)) and [Pixar](#).
14. [Commercial research lab pages](#): [Microsoft Research Asia](#), [Microsoft Research U.S.](#), and [Cesium](#) (GIS).
15. The [Level Up Report](#) by Mark DeLoura is a free weekly that provides pointers to all sorts of developments and resources for learning through games, coding, and making.
16. [Level 80](#) has a constant stream of information for game artists and content creators.
17. [Free \(and good\) books online](#)

Course organization

Course note

- This course is not about art, design, game-development, film, visualization for engineering and science domains, etc.
- This course gives foundations for creating imagery for arbitrary discipline
- Computer graphics is a tool to create beautiful imagery - but tool alone is not enough to create those images!
 - If you are interested in applying graphics to specific domain area (game, film, sci-vis, etc.) I encourage you to obtain the required domain knowledge as well!

About lecturer

- My background
- My interests
- My experiences

About you

- What is computer graphics for you?

Course contents

- Lectures
- Project
- Exam

Lectures plan

10 lectures; 3 x 45min

- Lecture 1: introduction (this) and rendering overview
- Lecture 2: 3D scene – transforms and shapes
- Lecture 3: 3D scene – materials: scattering and texture
- Lecture 4: 3D scene - lights and cameras
- Lecture 5: Rendering - rendering introduction and raytracing
- Lecture 6: Rendering - rasterization
- Lecture 7: Images – image + project
- Lecture 8: More on 3D scene + project
- Lecture 9: More on rendering + project
- Lecture 10: More on image + project

Lectures

- The point of lectures is to give the structure and to give highlights on foundations
 - They are starting point, a map, which is for you to explore.
 - Consultations are always possible!
- During lectures write down important points ask if anything is unclear
 - Feel free to interrupt! If something is not clear for you it is a high possibility it is also not clear for someone else – it is good to repeat!

Map of computer graphics

- Point of lectures is to give structure and it is up to you to fill it.

Note for slides

- Note for slides
 - Slides were intended for both lectures and as reading material. Therefore, some slides contain a lot of text which is intended for student to read at home. Those slides will have special icon.
 - Important elements will be highlighted and noted that they should be written down by hand
 - Your interaction is crucial for best learning experience

Questions

Reading material

Write it down

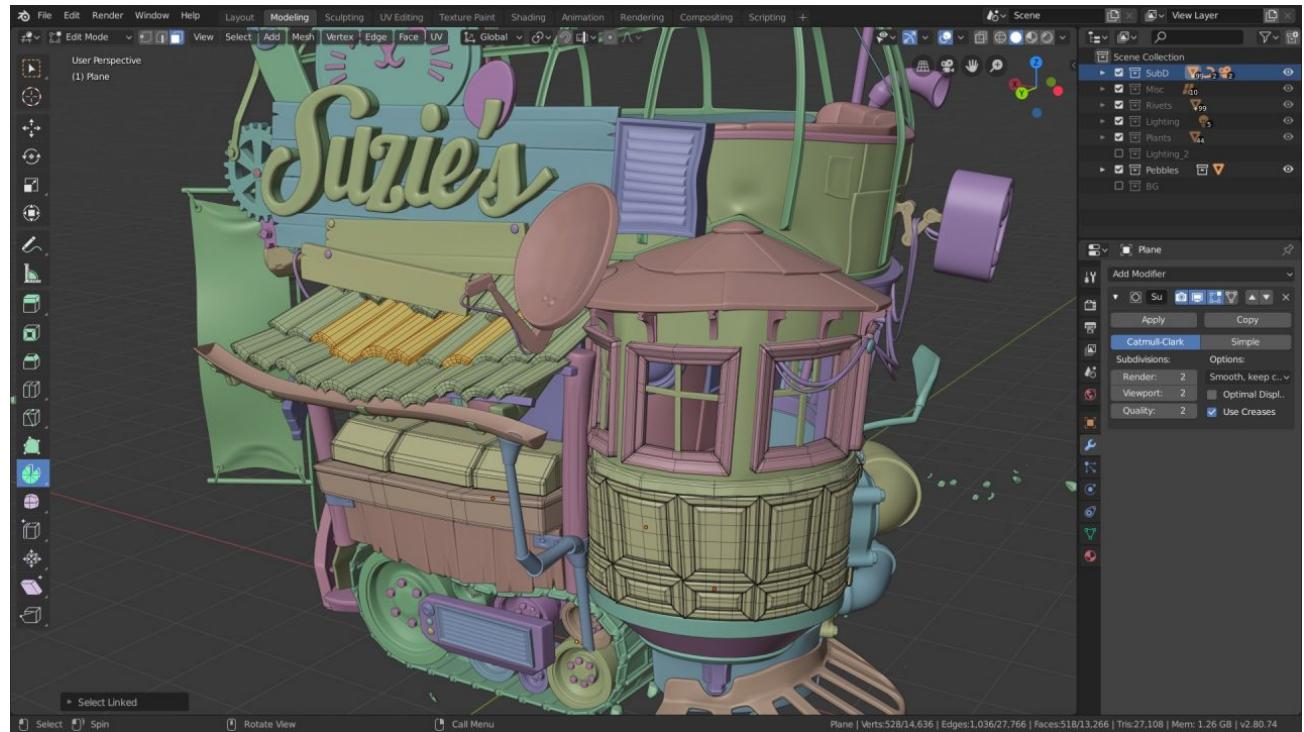
Useful web sites

Additional learning material

- Books
- Useful sites

Tools for learning and experimenting

- Blender is our friend: <https://www.blender.org/>



Projects

- During lectures we will cover wide range of methods and ideas conceptually
- During project work, you will have time to dive deeper into technical aspects and implementations of what is the most interesting to you.

Projects

- TODO: shortly describe projects + add images of what results might look like
 - Low level of abstraction: coding and focus on rendering
 - High level of abstraction: modeling, animation and interaction in DCC or game engine
- <https://github.com/lorentzo/IntroductionToComputerGraphics/wiki/Projects>
- Projects: a time dedicated to experience real-life development (and research).
 - Projects can be started even after this lecture: decide on topic and start investigating!.
 - Projects should be time for you to research and work on your own - consultations are always possible!
 - Projects are made to be fun and engaging: choose what you like!

Course outcomes

- Understand fundamental concepts and theory: those are immortal
- Typically mathematics, algorithms and methods used in computer graphics
- Understanding how foundations are supporting technology and which technology exists for you to create
- Map of the computer graphics

Special outcomes

- “Seeing world with different eyes”
 - Example: shadows – with and without
- Foundations for expression and visualization

Course web-site and materials

- These presentations and your notes
- <https://github.com/lorentzo/IntroductionToComputerGraphics>
- All materials are available in advance
 - TIP: read materials before lecture – it helps for following the lecture

Course grading

- Project
 - Based on solved steps
- Exam
 - 30min, online, Moodle