# CSCI 420: **Computer Graphics**

***Fall 2018***

Hao Li

**http://cs420.hao-li.com**

http://hao.li/

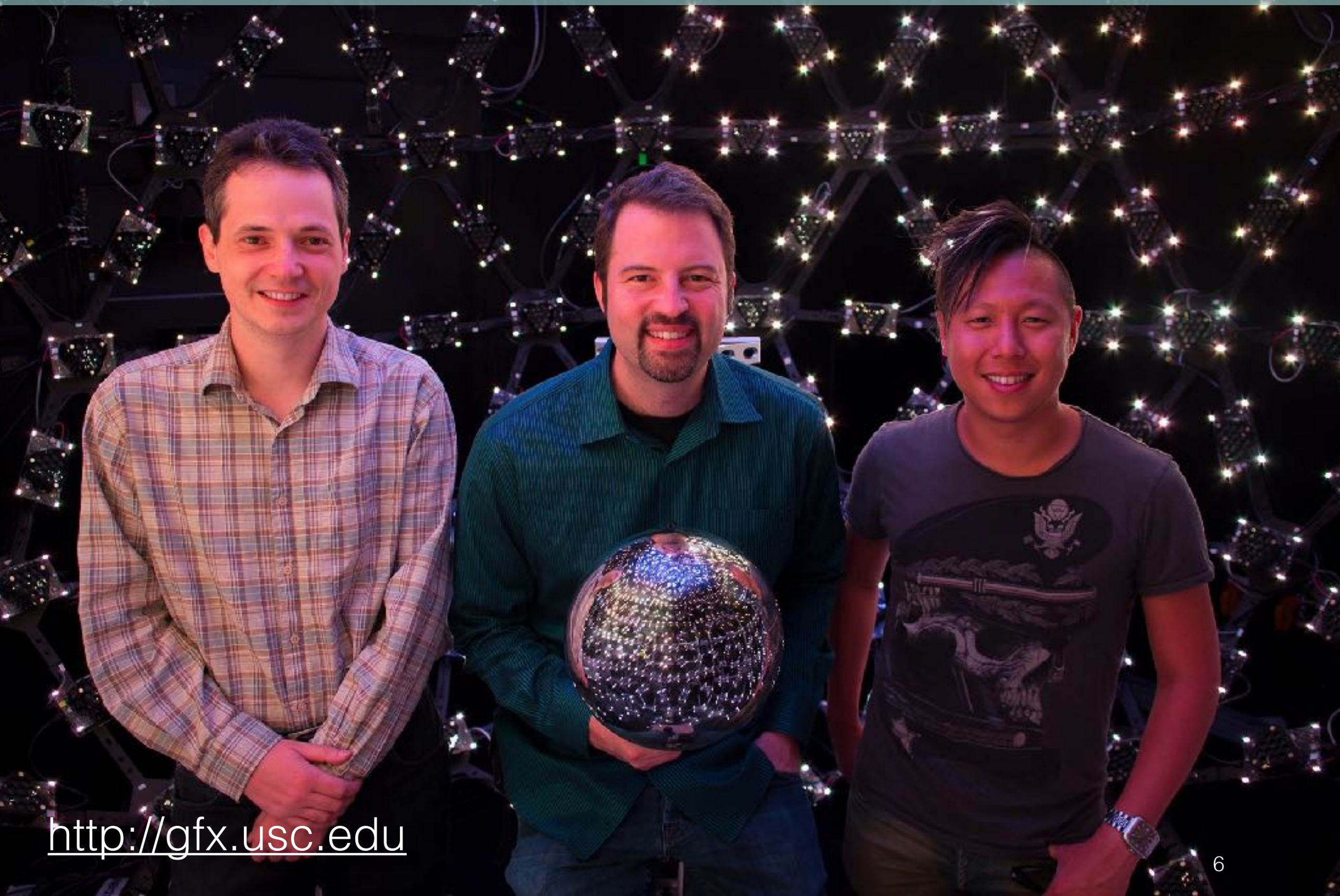
# Vision & Graphics [Lab]

# About Me

# Industrial Light & Magic

# Weta Digital

# USC Graphics



http://gfx.usc.edu

pinscreen

ICT
INSTITUTE FOR CREATIVE TECHNOLOGIES

# Science, Engineering, & Art

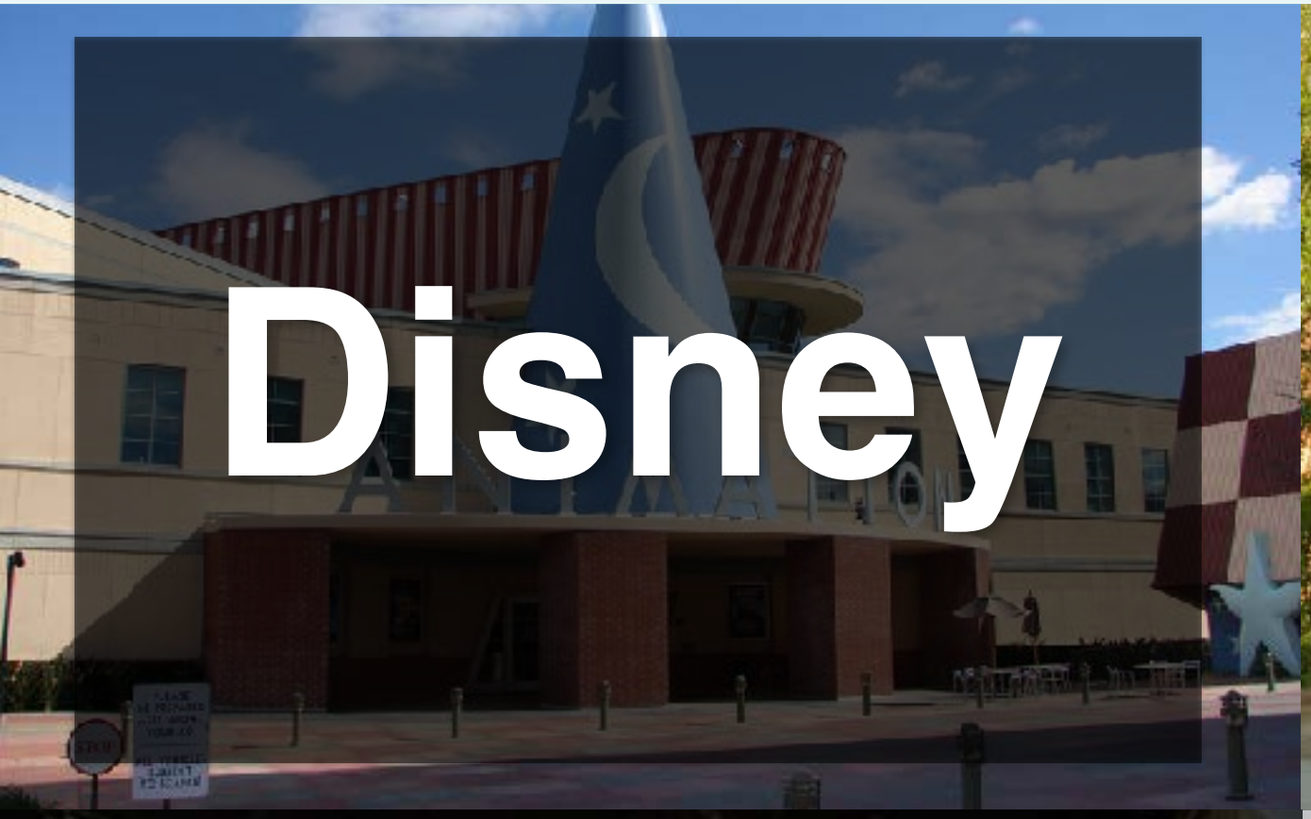
USC Viterbi
School of Engineering

USC School
of Cinematic Arts

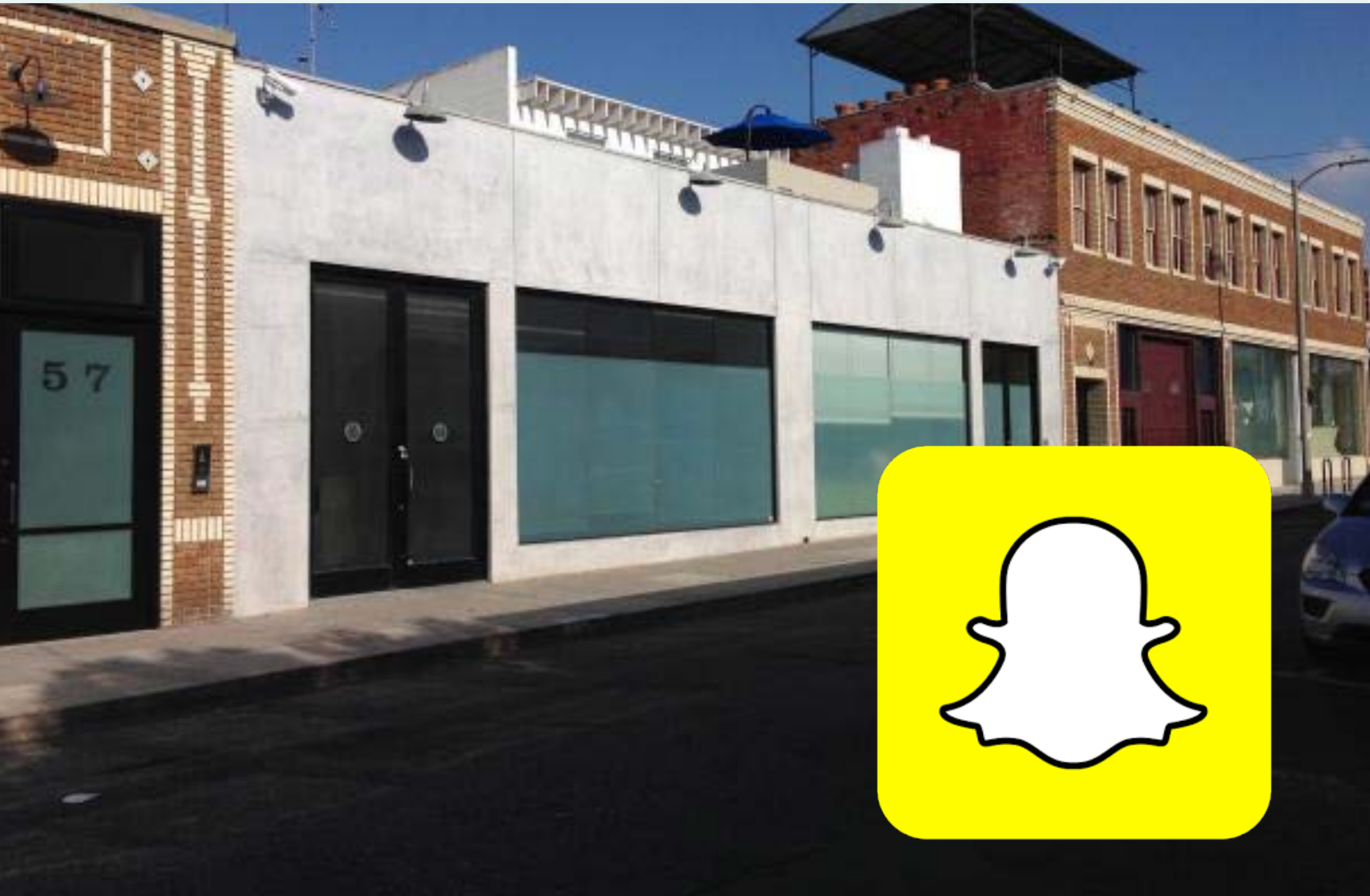
USC ICT
INSTITUTE FOR CREATIVE TECHNOLOGIES

USC Games

# **High Tech** & Capital of Entertainment

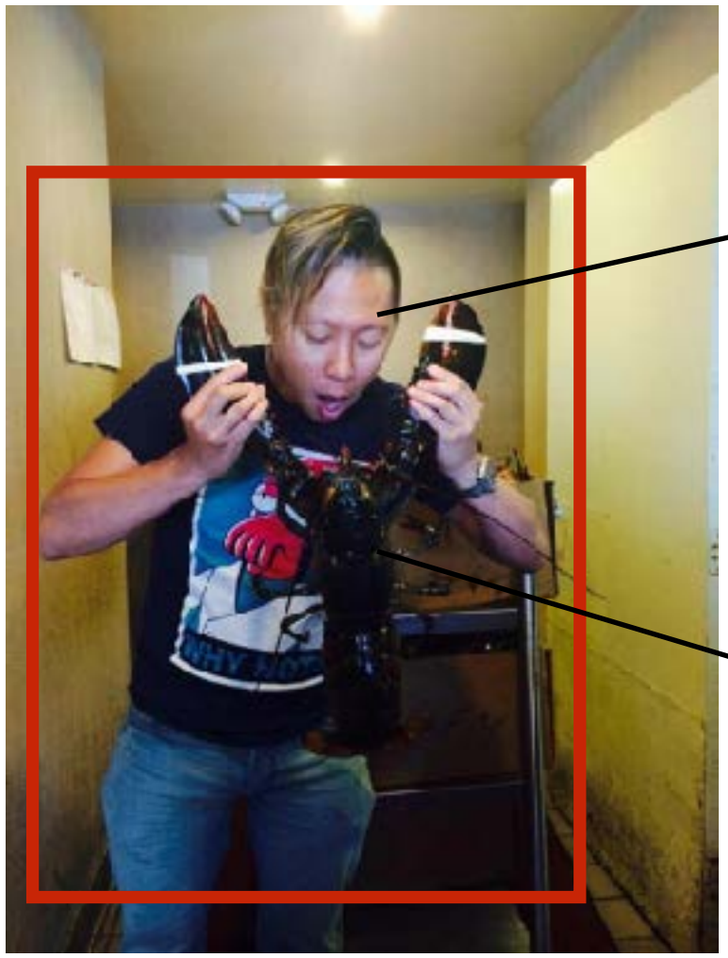


# Silicon Beach



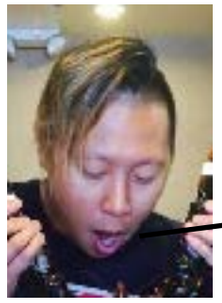
# Computer Graphics vs. Vision

# Computer Vision

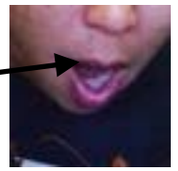


ROI

input
an image



face



mouth open 70%

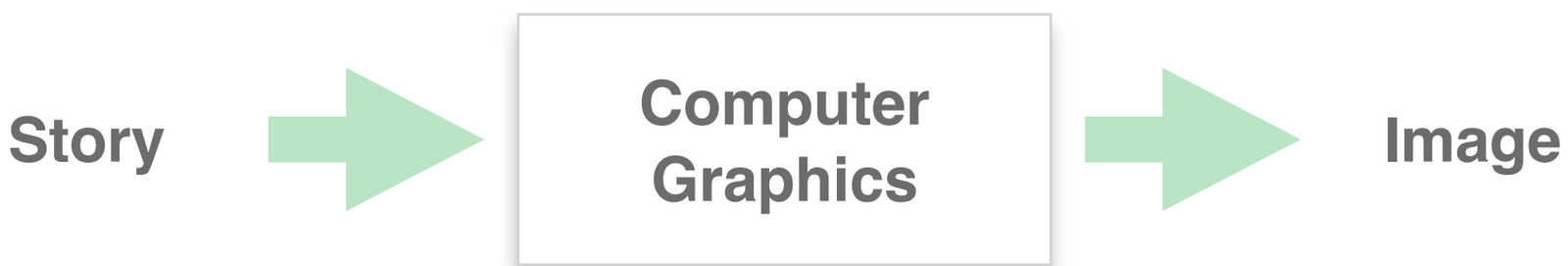
shrimp 20%
lobster 60%
crap 40%

output
Hao is eating a lobster

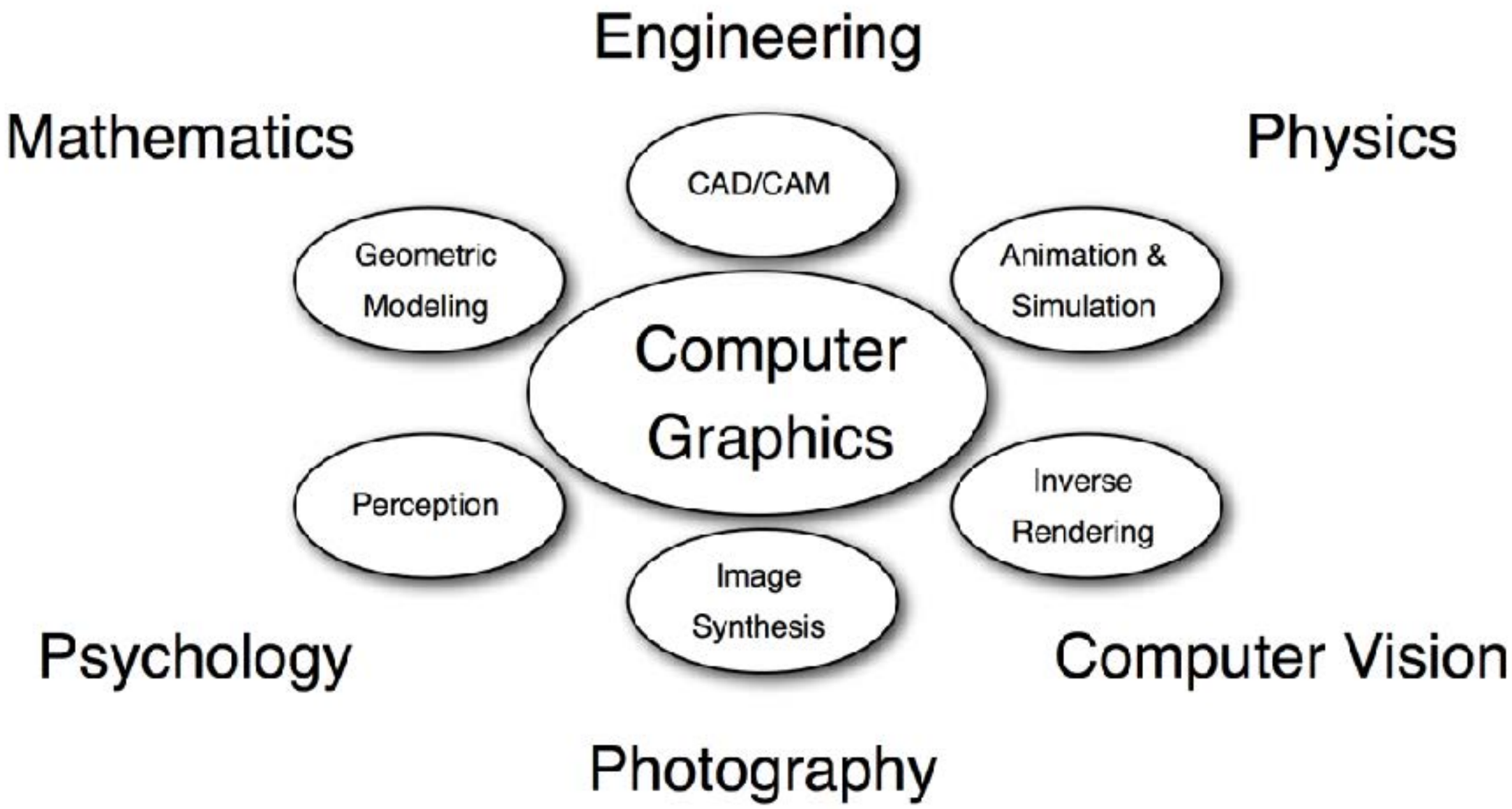
**Image** → **Computer Vision** → **Story**

# Computer Graphics

and… Action!

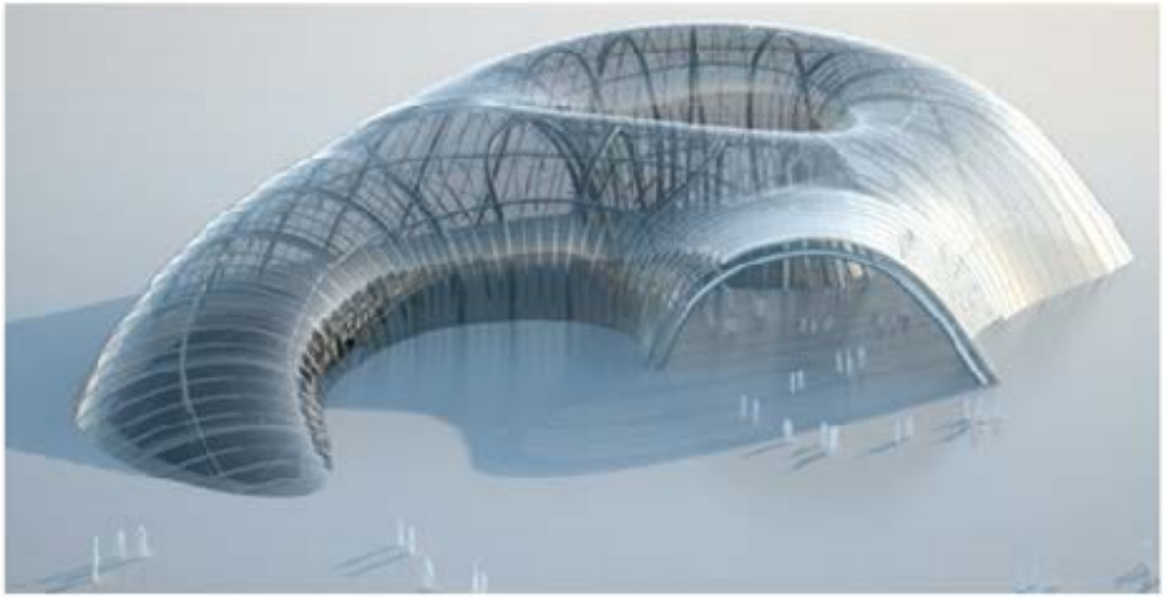


# Related to many Disciplines



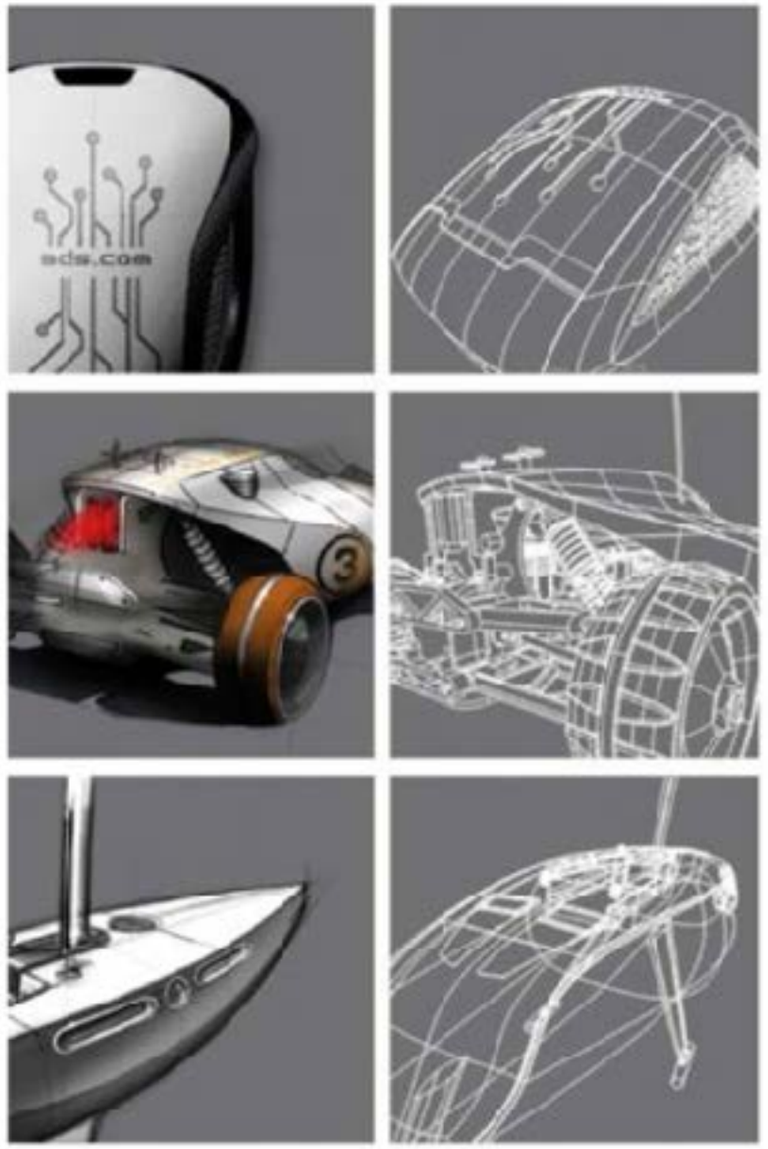
# Applications

# Computer Aided Design



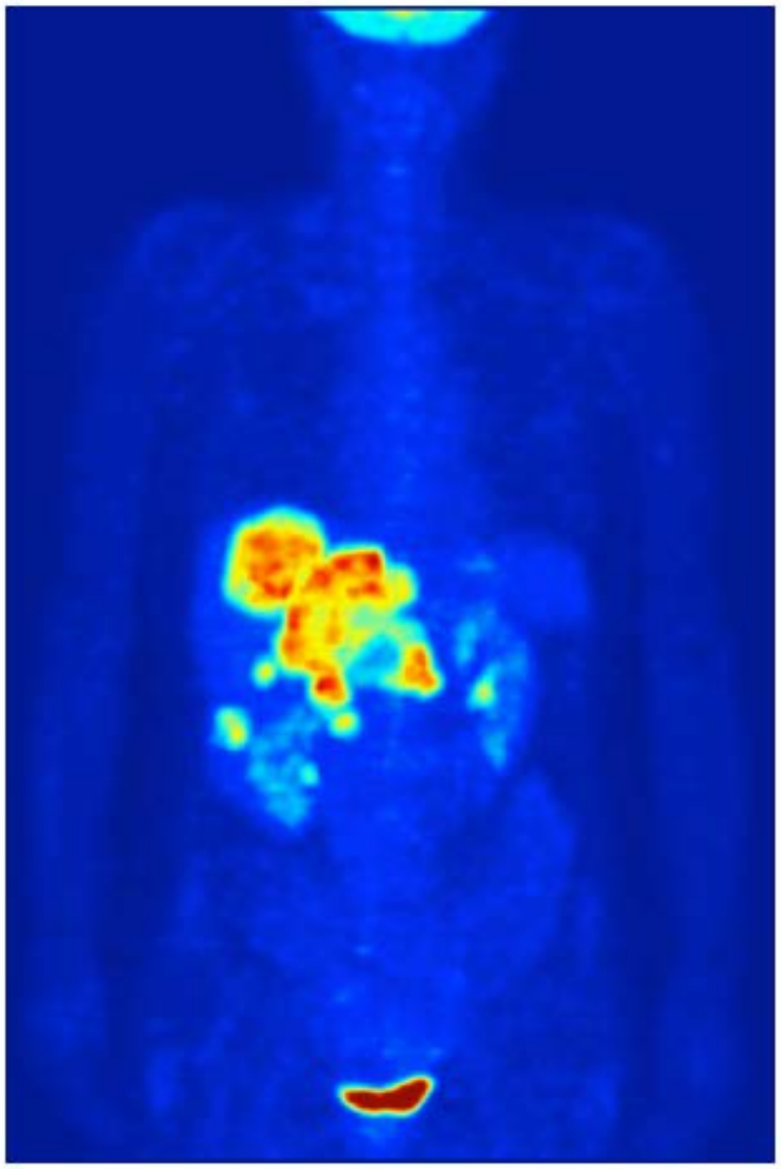
evolute - architectural design

cyberswift - mechanical design

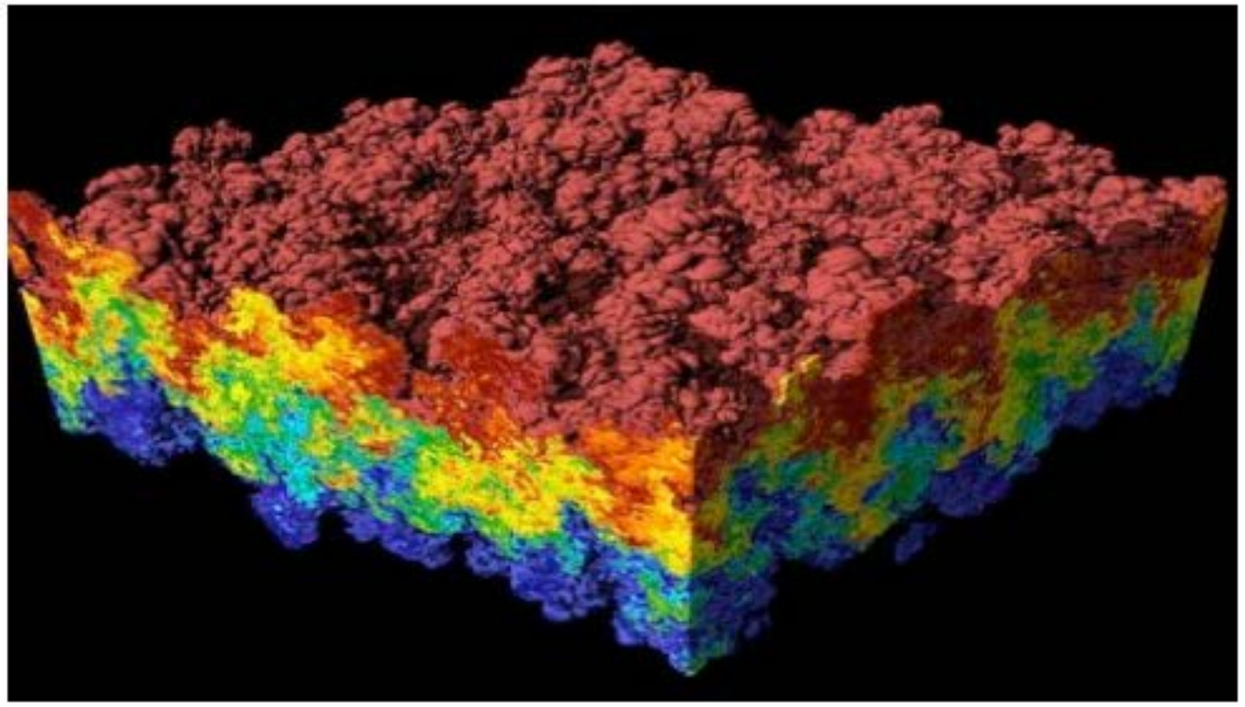


catia - product design

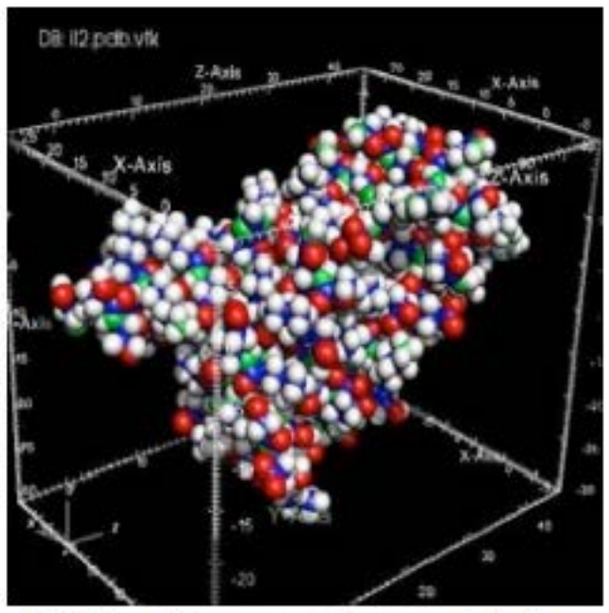
# Scientific Visualization



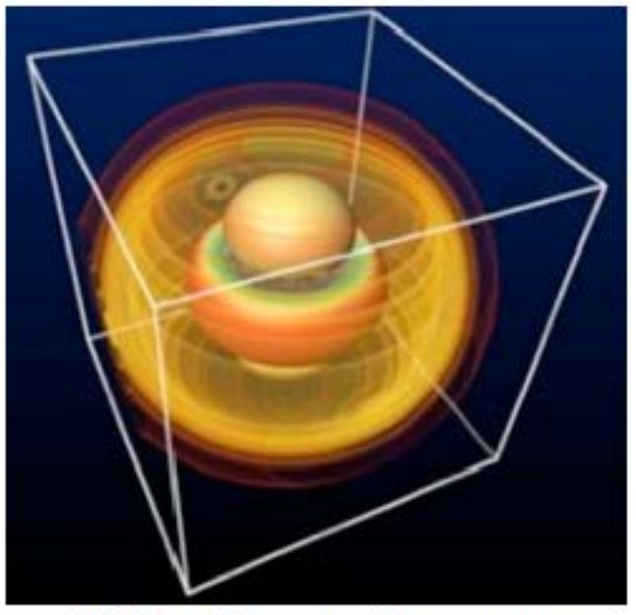
Wikipedia -PET scan



Wikipedia - mixing fluids




Wikipedia - protein rendering



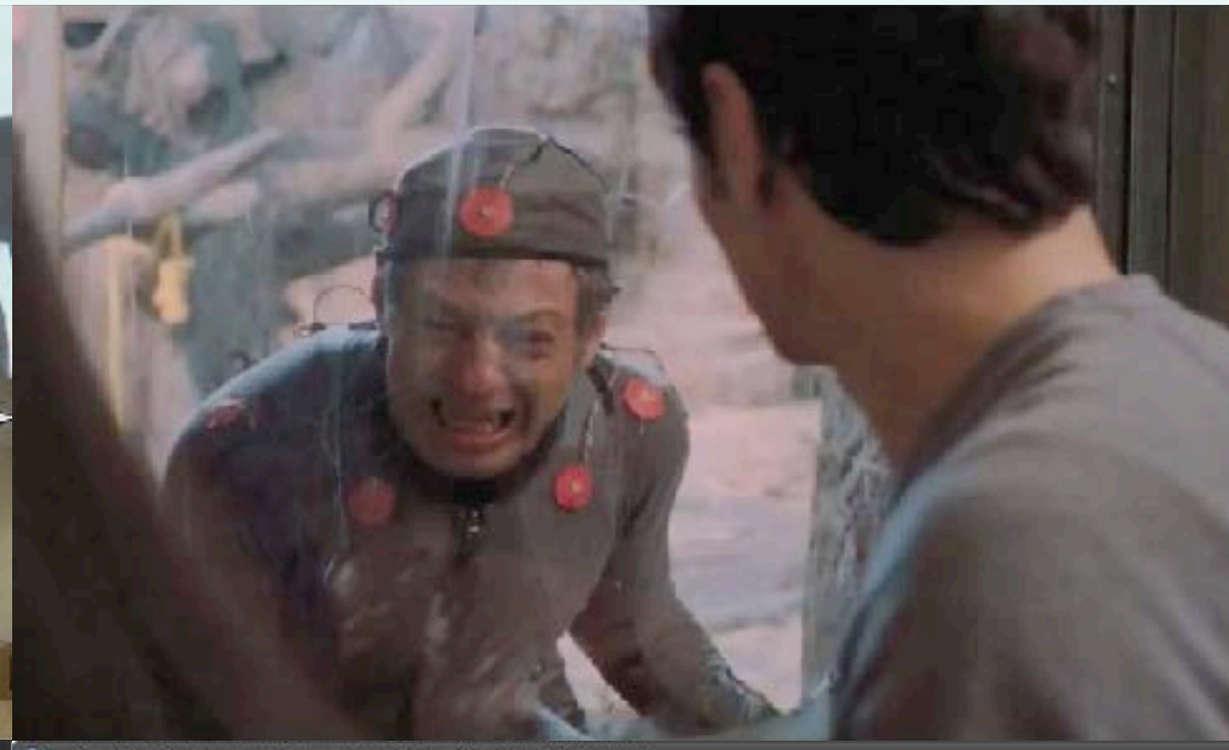
Wikipedia - gravity waves

# Training / Simulation

Microsoft - flight simulator

Aalborg University - surgery simulation

# Entertainment

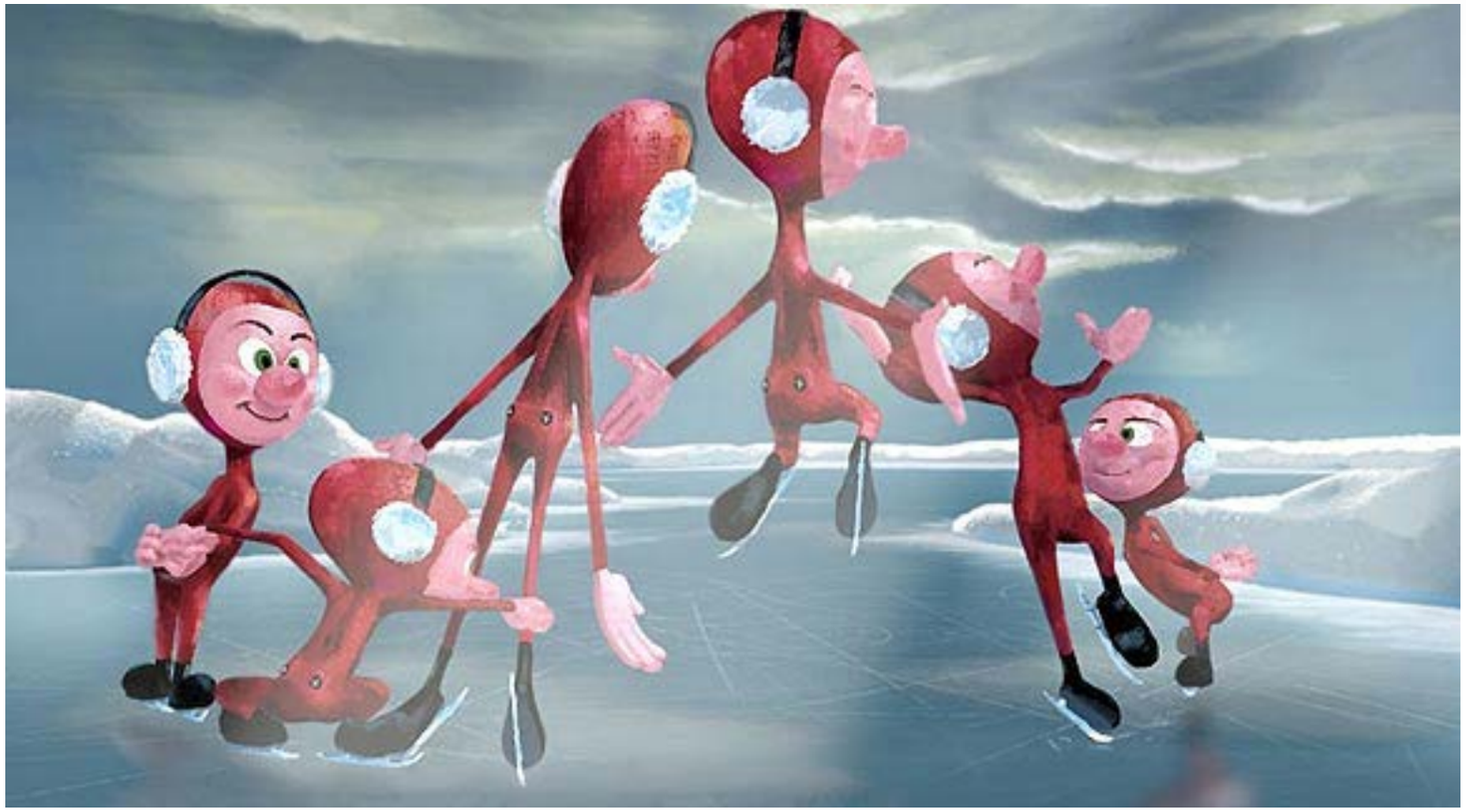


# VFX

# Games

# Computing Illustrations

A. Hertzmann, D. Zorin
SIGGRAPH 2000



Pixar

Non-Photorealistic Rendering (NPR)

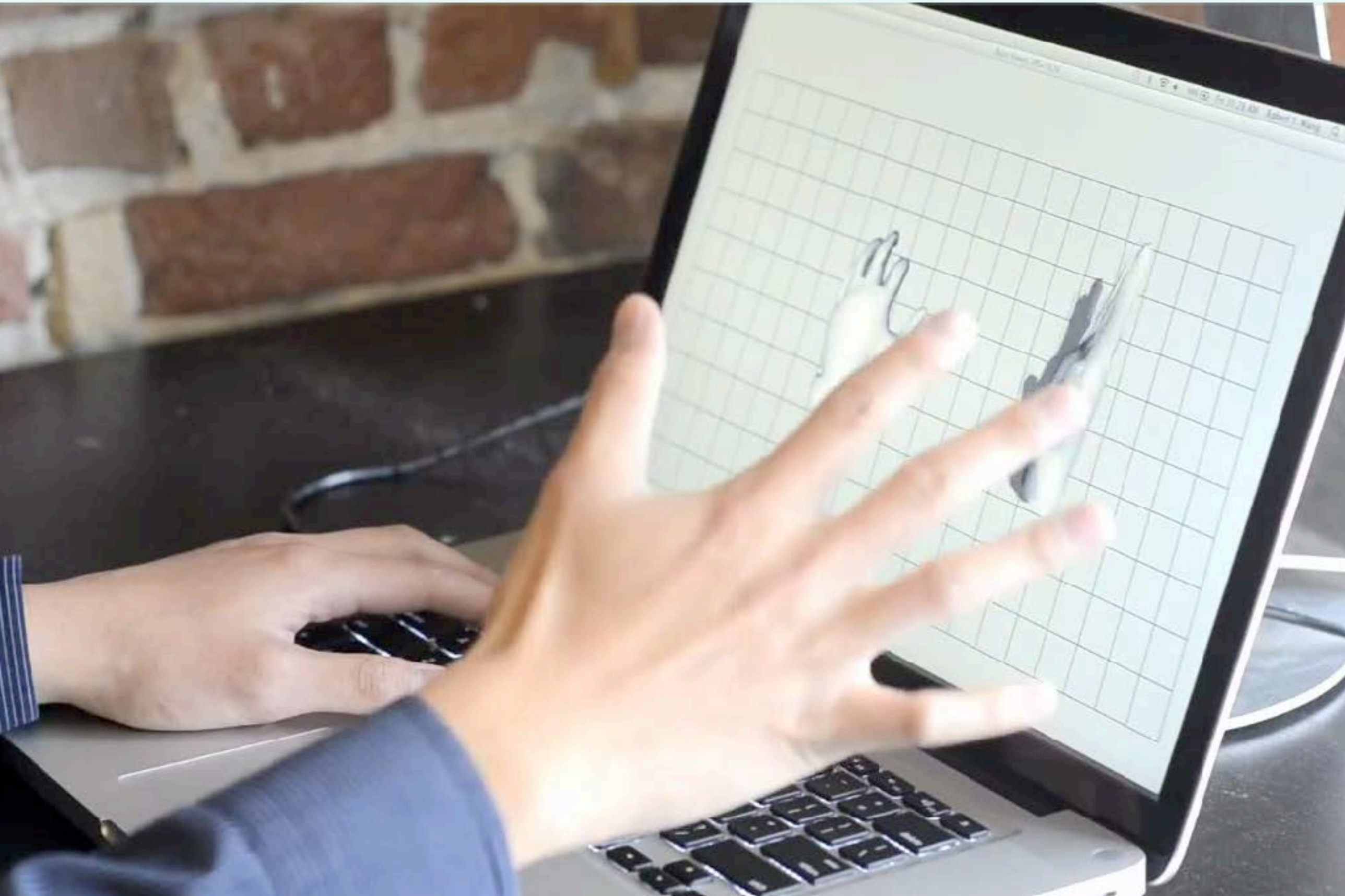
# Into the Mainstream

# Home Entertainment

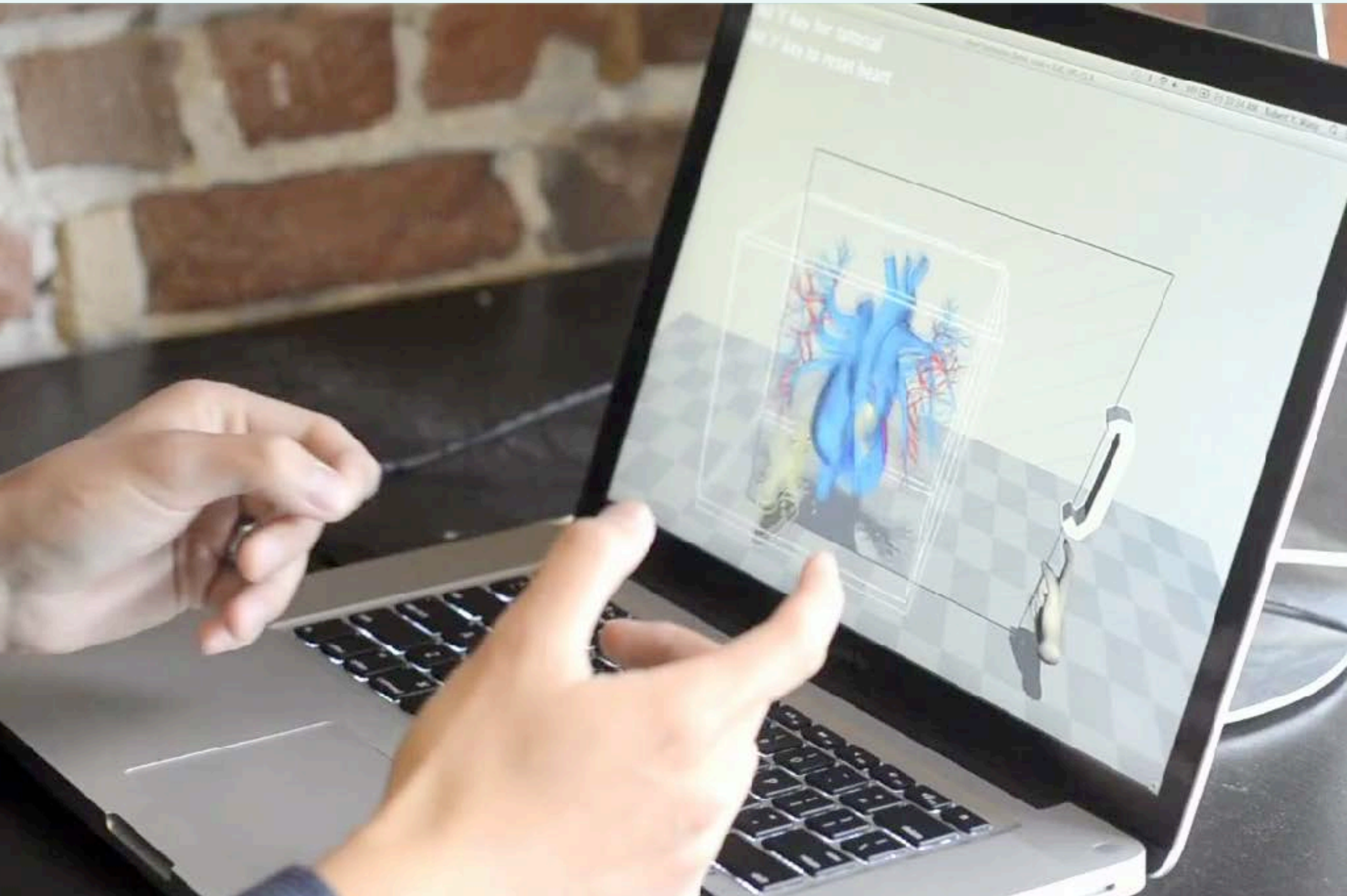
# Human Computer Interfaces

# In Tablet

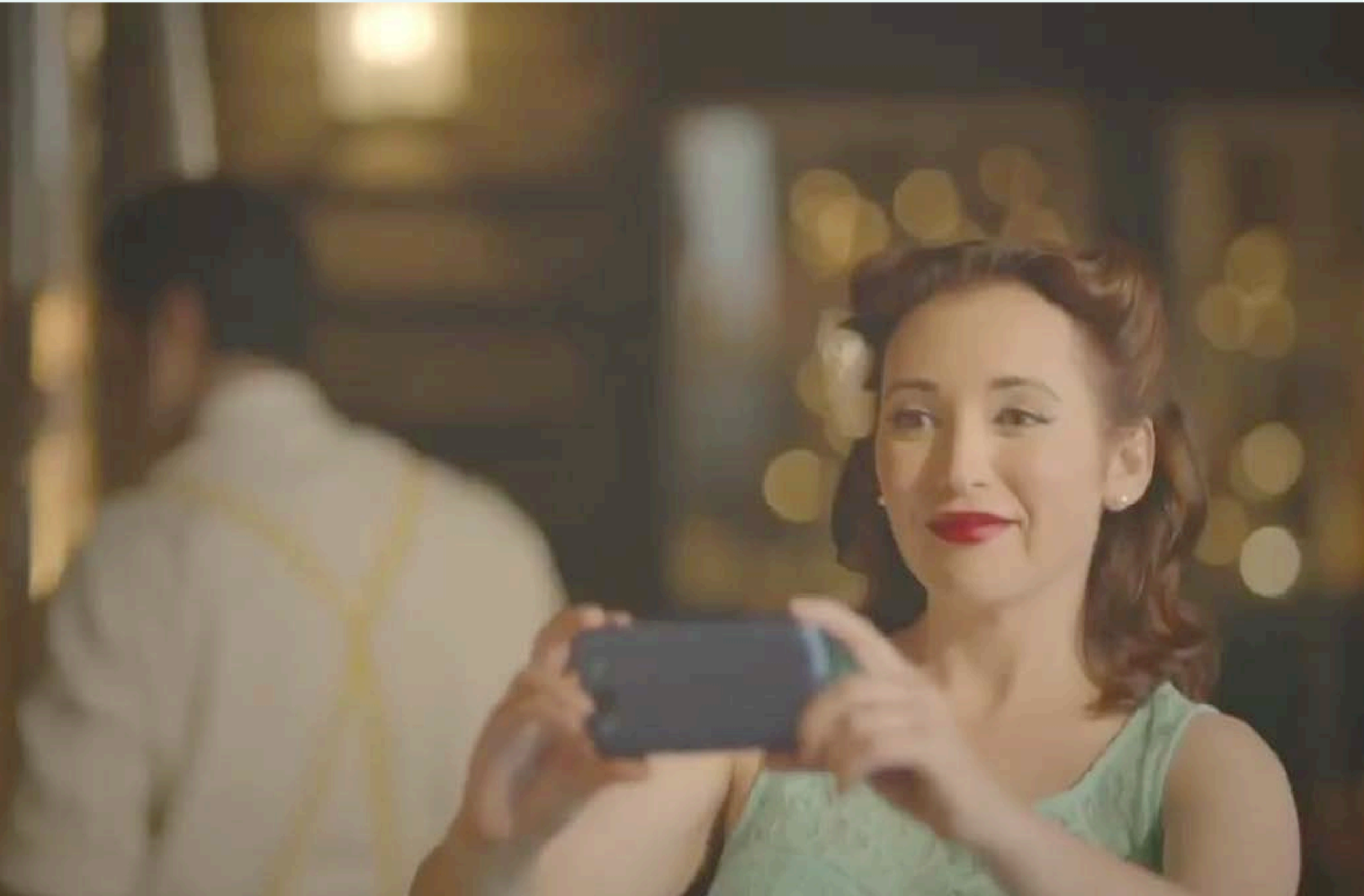
# Laptops



# Laptops



# Smartphones



# 3D Printing

# Fashion Industry

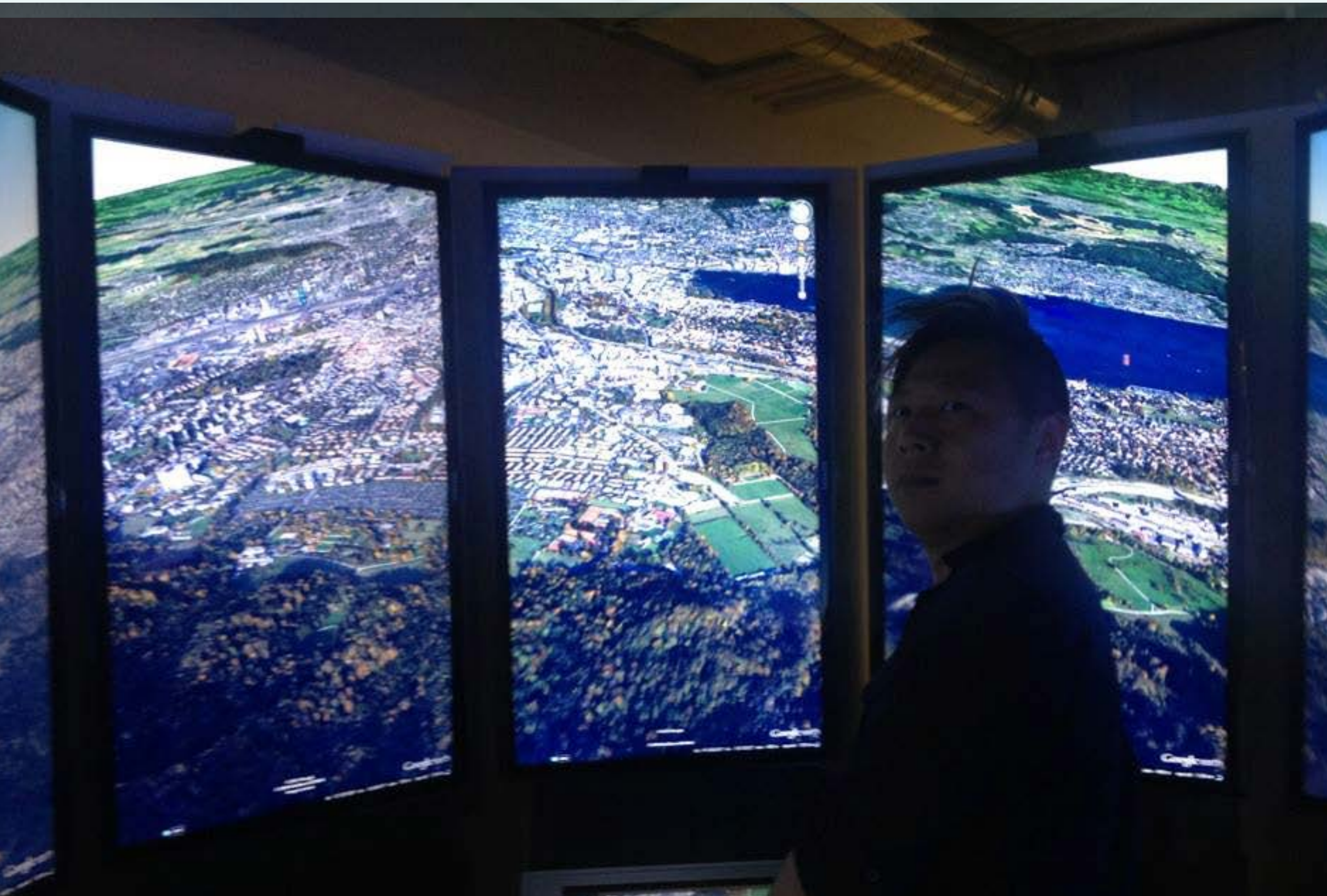
LE TOTE

Your closet 2 expanded.

phisix

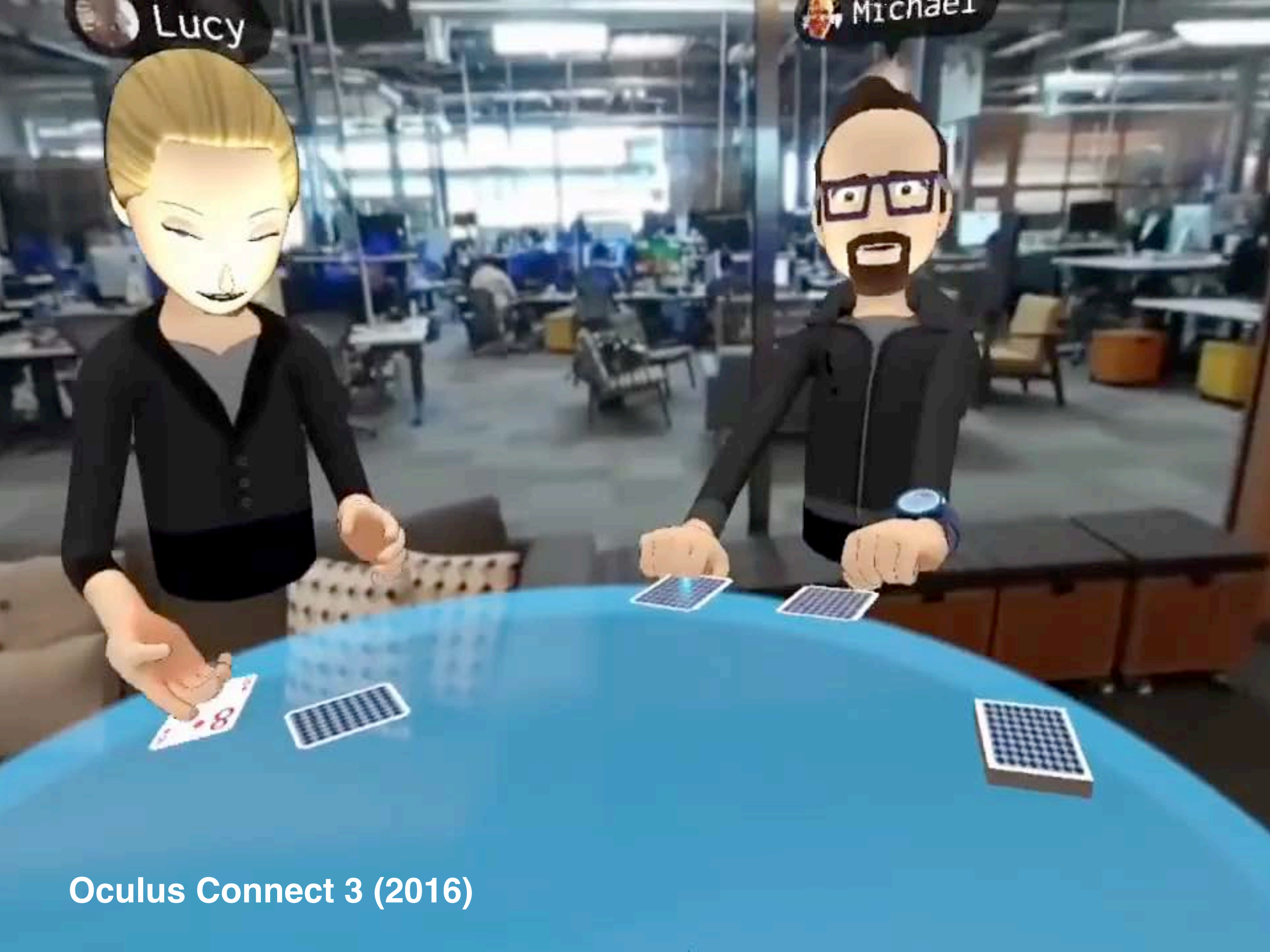
# 3D Cities

# Google Earth



# Oculus VR

Oculus Connect 2 (2015)

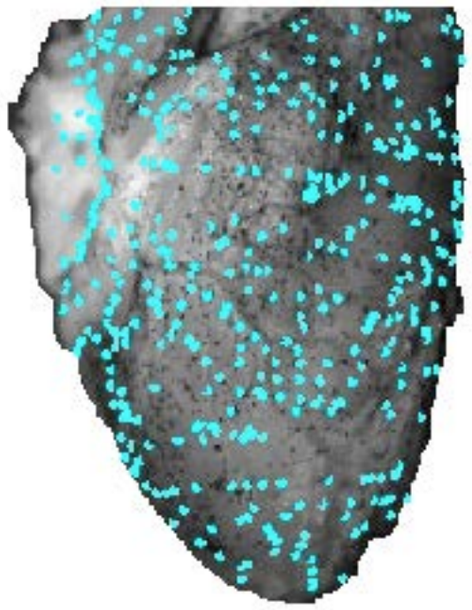


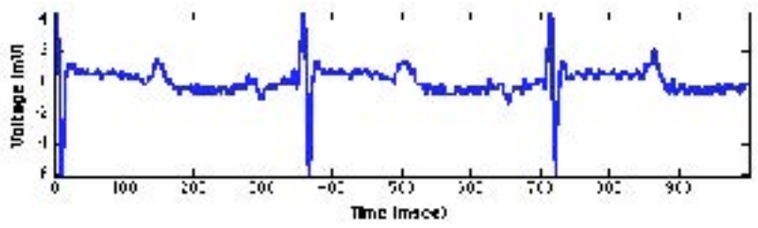

## Oculus Connect 3 (2016)

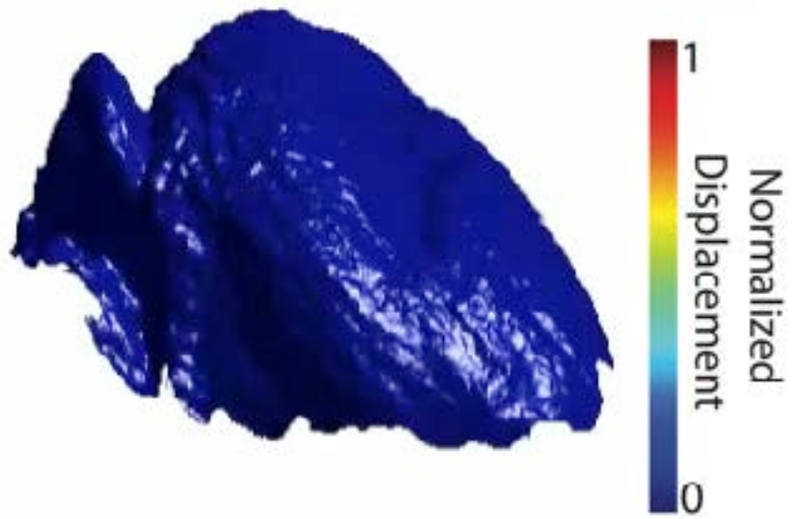
# AR

# Impacting Science

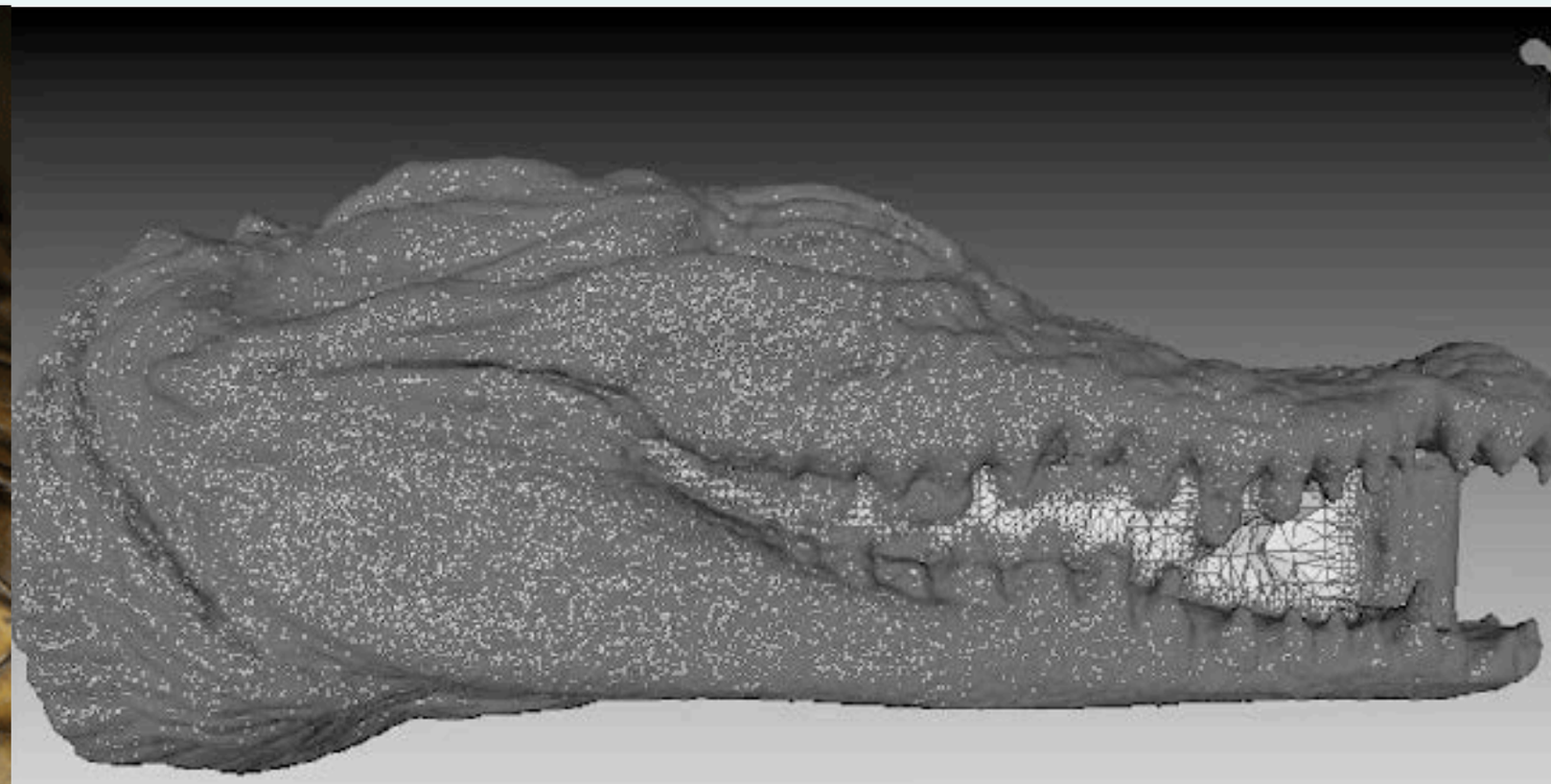
# Cardiology





# Evolutionary Biology



# Cancer Treatment

# Target Audience

- **MSc** students, undergraduates, or interested **PhD** students
- **Computer Science**, Computer Engineering, Mathematics, Physics, Game Program, Biomedicine, Bioengineering, etc.
- Computer Graphics, Computer Vision, Robotics, Machine Learning, Signal and Image Processing, Medical Imaging

# Administrative Stuff

# Administrative

## When and where?

- Tuesday, 3:30 pm - 6:50 pm
- Discussions on Thursday, TBA and only when announced
- ZHS 352 (Zumberge Hall), 3651 Trousdale Parkway

## Credits

- 4 Units

## This week

- No Discussion

# The **Team**

## Instructor

- Hao Li, hao.li@usc.edu
  - Office: SAL 244
  - Office hours: Tue, 2-3 PM

## Teaching Assistants

- Haiwei Chen, haiweich@usc.edu
  - Office: PHE 108
  - Office hours: Wed, 12:30-1:30 PM
- Kyle Morgenroth, kmorgenr@usc.edu
  - Office: PHE 108
  - Office hours: Mon, 3:00-4:00 PM

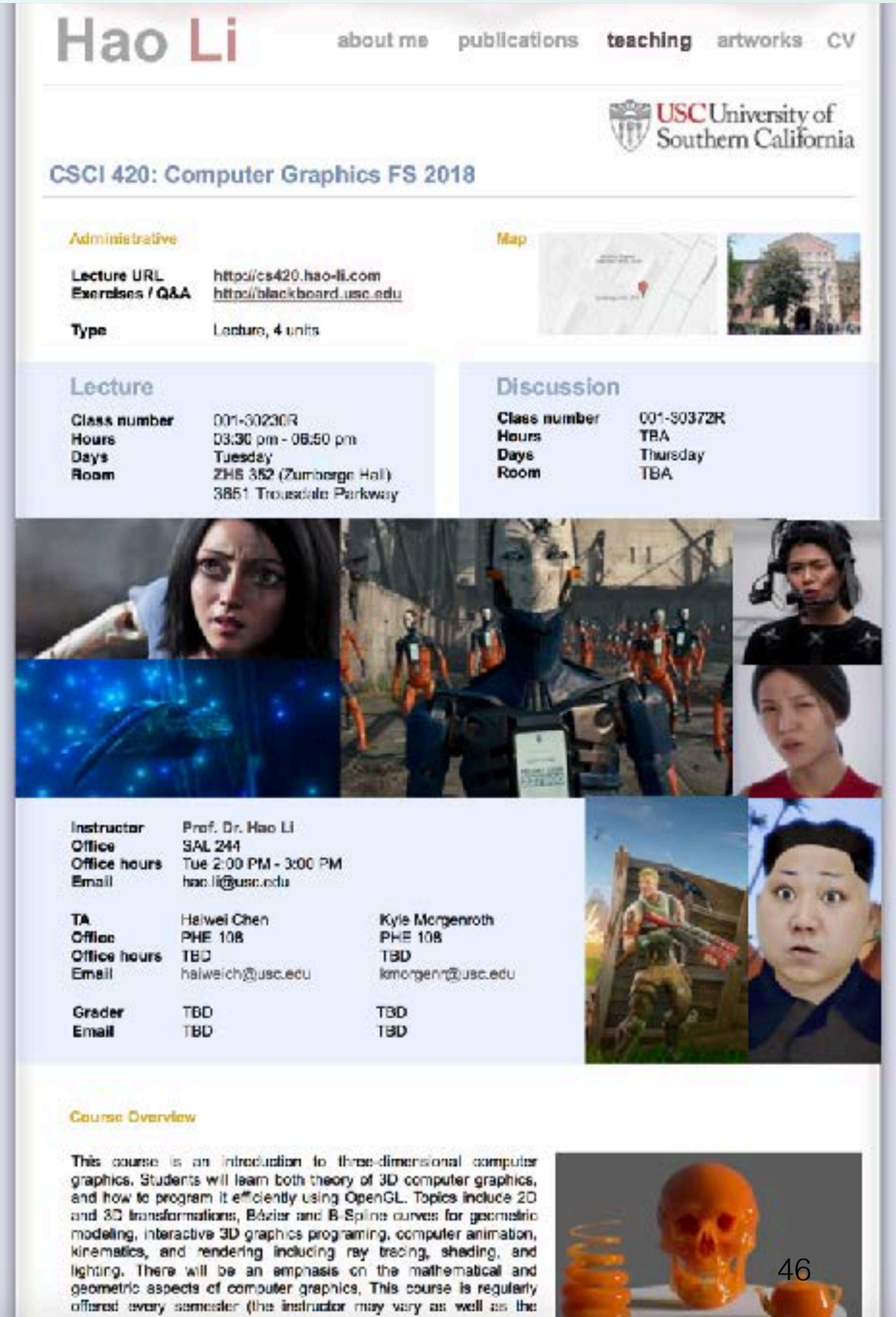
# Course Information On-Line

## http://cs420.hao-li.com/

- Schedule (slides, readings)
- Assignments (details, due dates)
- Software (libraries, hints)
- Resources (books, tutorial, links)

## http://blackboard.usc.edu/

- Submit assignments
- Forum, Q/A



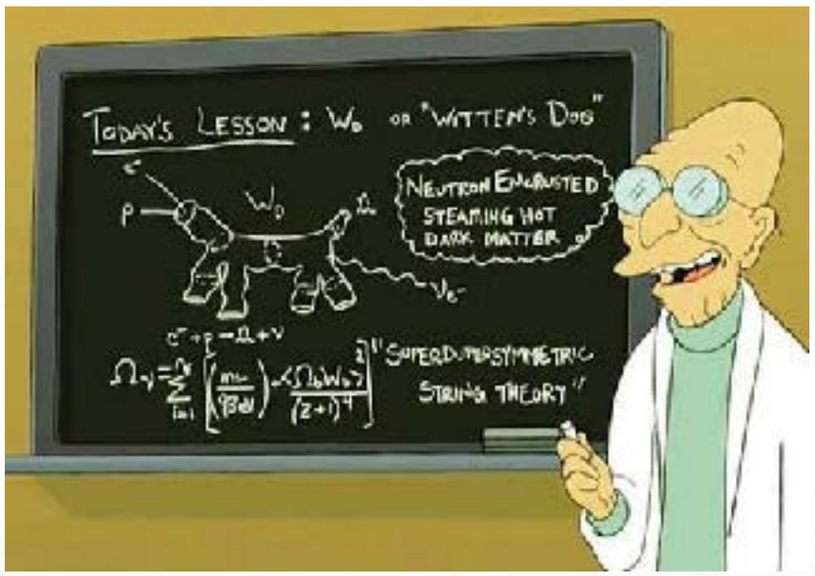
# Prerequisites

## Math

- Math 225 (Linear Algebra and Differential Equations)
- Familiarity with calculus and linear algebra

## Coding

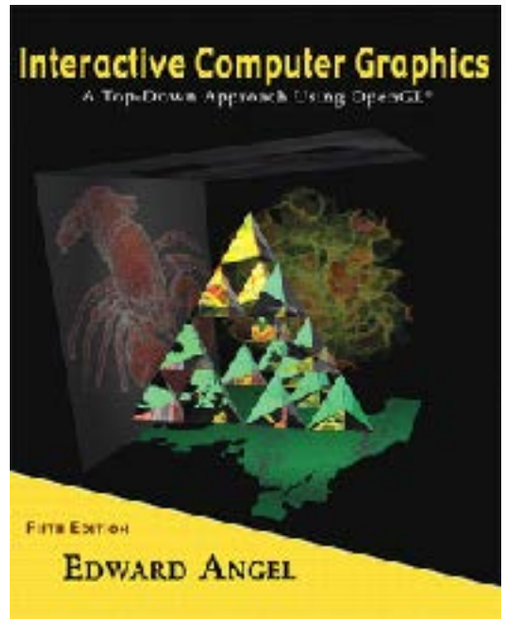
- CSCI 104 (Data Structures and Object-Oriented Design)
- C/C++ programming



# Textbooks

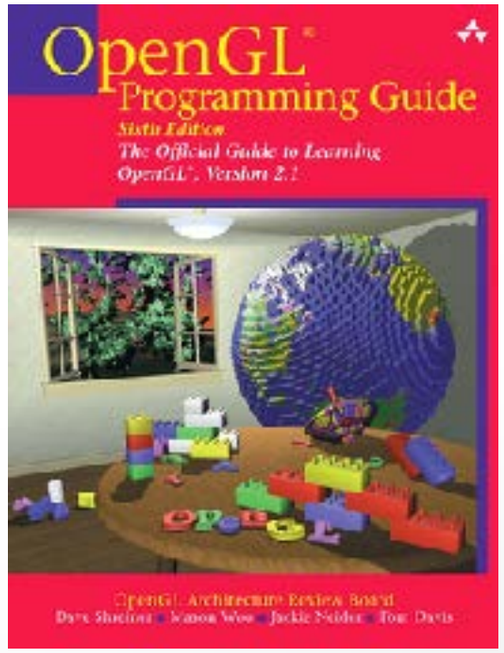
## Interactive Computer Graphics

- A top-down approach with OpenGL, Fifth Edition, Edward Angel, Addison-Wesley




## OpenGL Programming Guide ("Red Book")

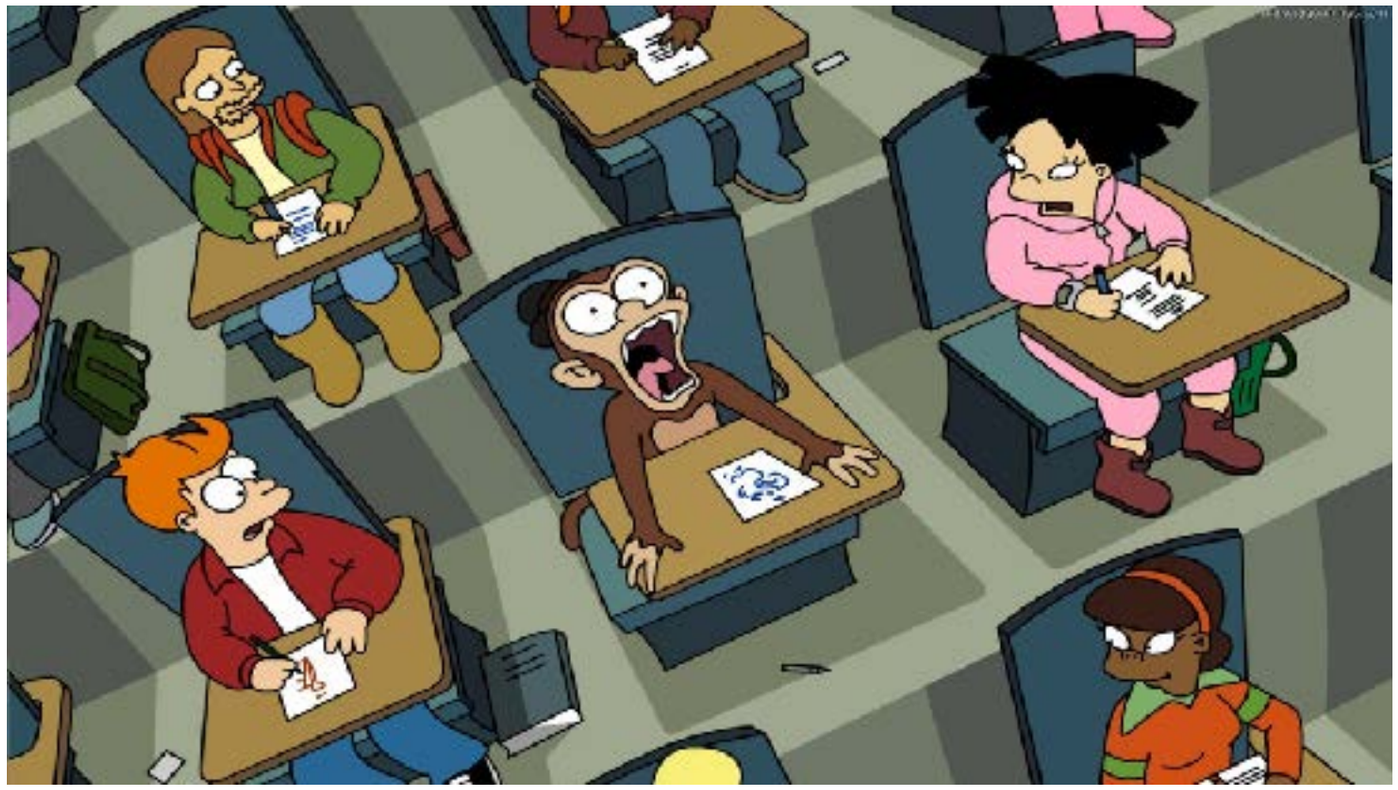
- Basic version also available on-line (see Resources)



# Grading

## Exercises

- Ex 1: 16 %
- Ex 2: 17 %
- Ex 3: 17 %



## Exams

- Midterm: 20% (one shee of notes only, in class)
- Final: 30% (one sheet of notes only)

# Academic Integrity

- Do not copy any parts of the assignments from anyone
- Do not look at other student's code
- Collaboration only for the project
- USC Office of Student Judicial Affairs and Community Standards (Hell) will be notified
- Don't cheat, mkay?

# Assignment Policies

## Programming Assignments

- Hand in via Blackboard by end of due date
- Functionality and features
- Style and documentation
- Artistic impression

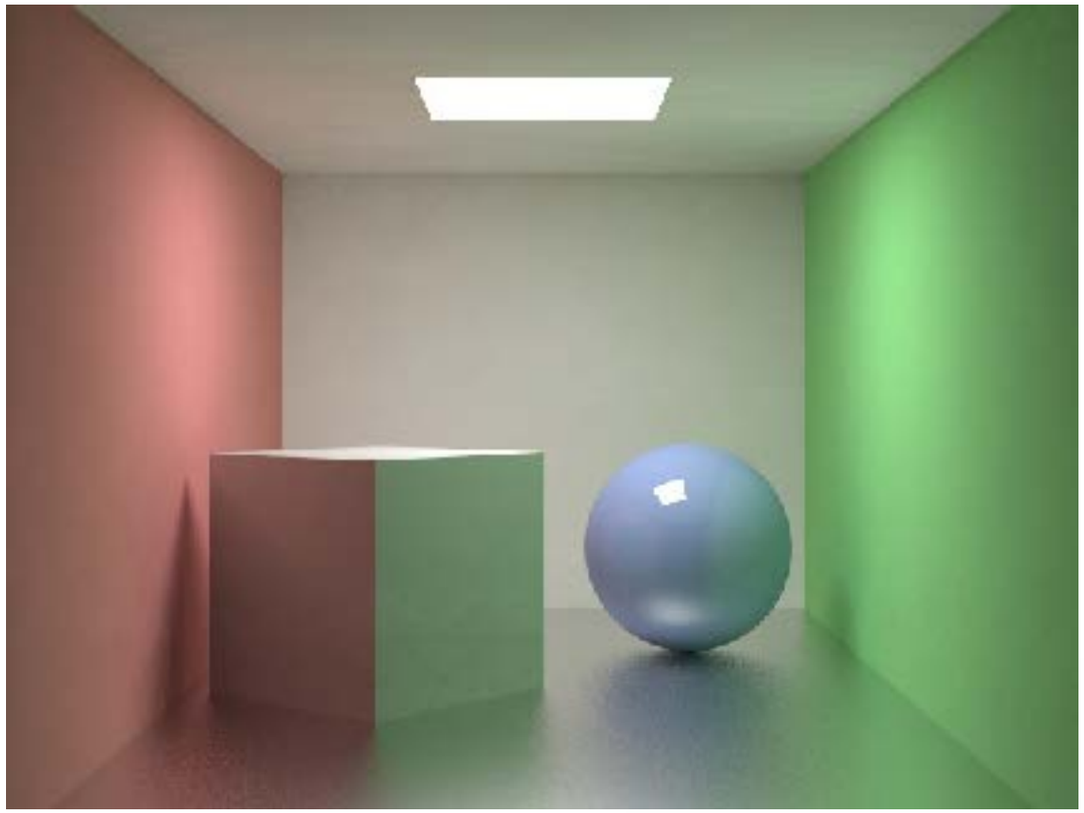
**3 late days, usable any time during semester**

**Academic integrity policy applied rigorously**

# Computer Graphics

## One of the “core” computer science disciplines:

- Algorithms and Theory
- Artificial Intelligence
- Computer Architecture
- **Computer Graphics**
- Computer Security
- Computer Systems
- Computer Vision
- Databases
- Machine Learning
- Networks
- Software Engineering



# Course Overview

## Theory / Computer Graphics Disciplines

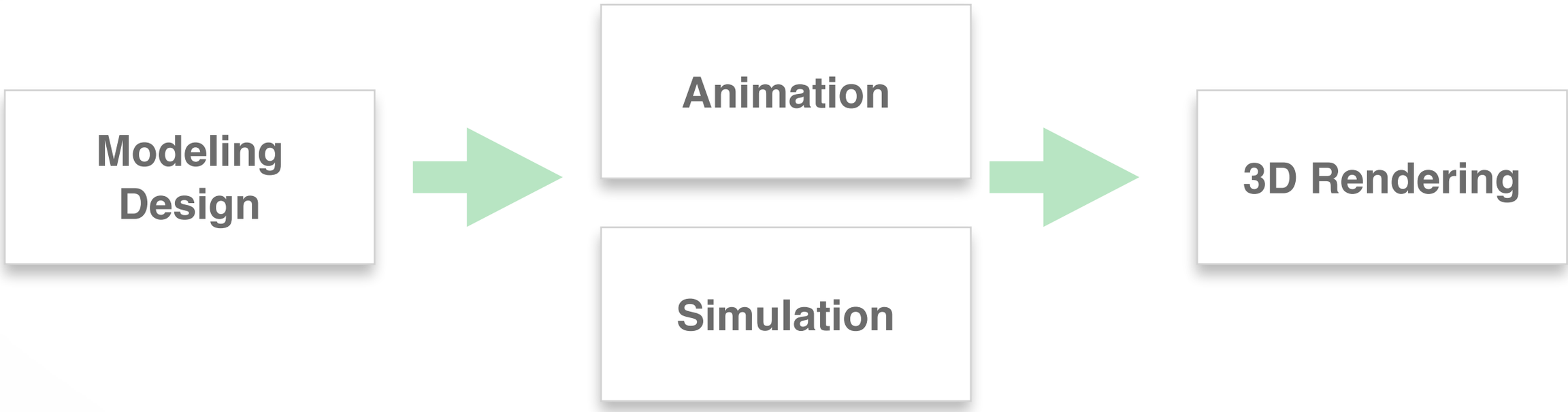
- Modeling: how to represent objects
- Animation: how to control and represent motion
- Rendering: how to create images of objects
- Image Processing: how to edit images

## Practice: OpenGL graphics library

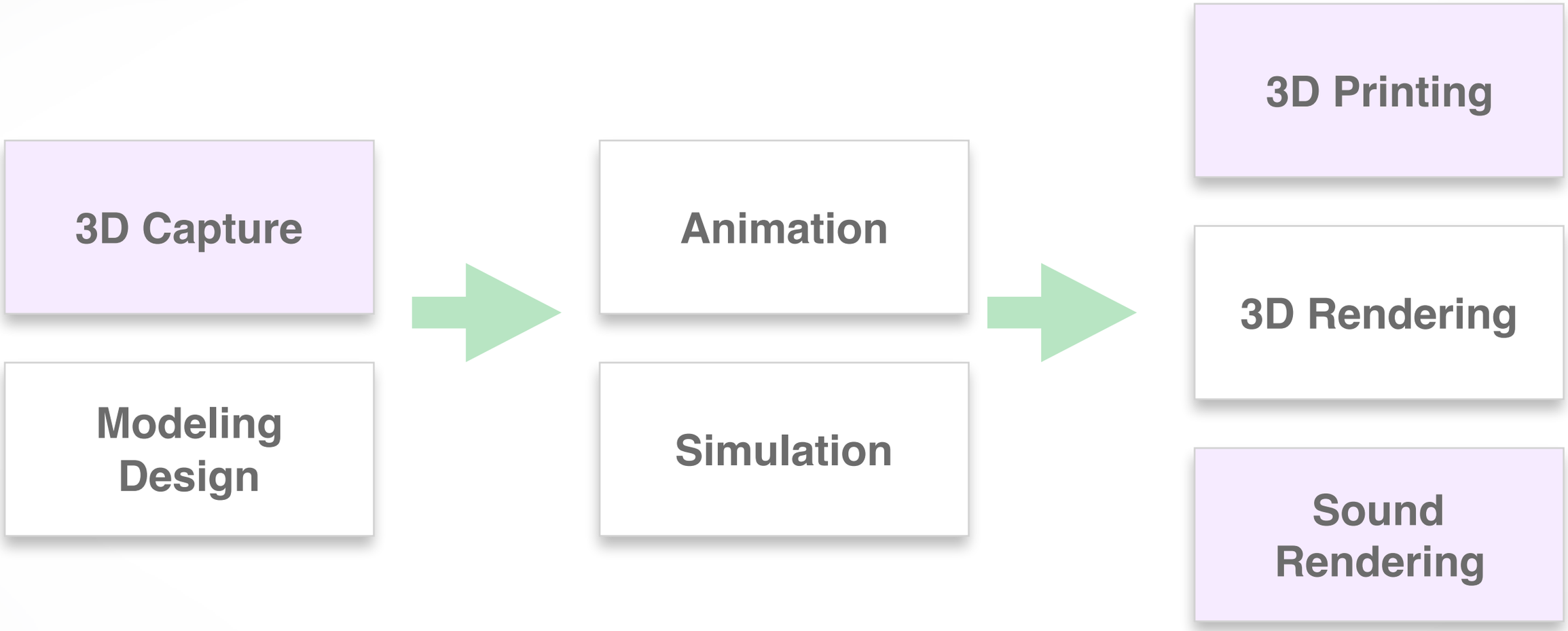
## Not in this course:

- Human-Computer Interaction
- Graphic Design

# 3D Computer Graphics Pipeline



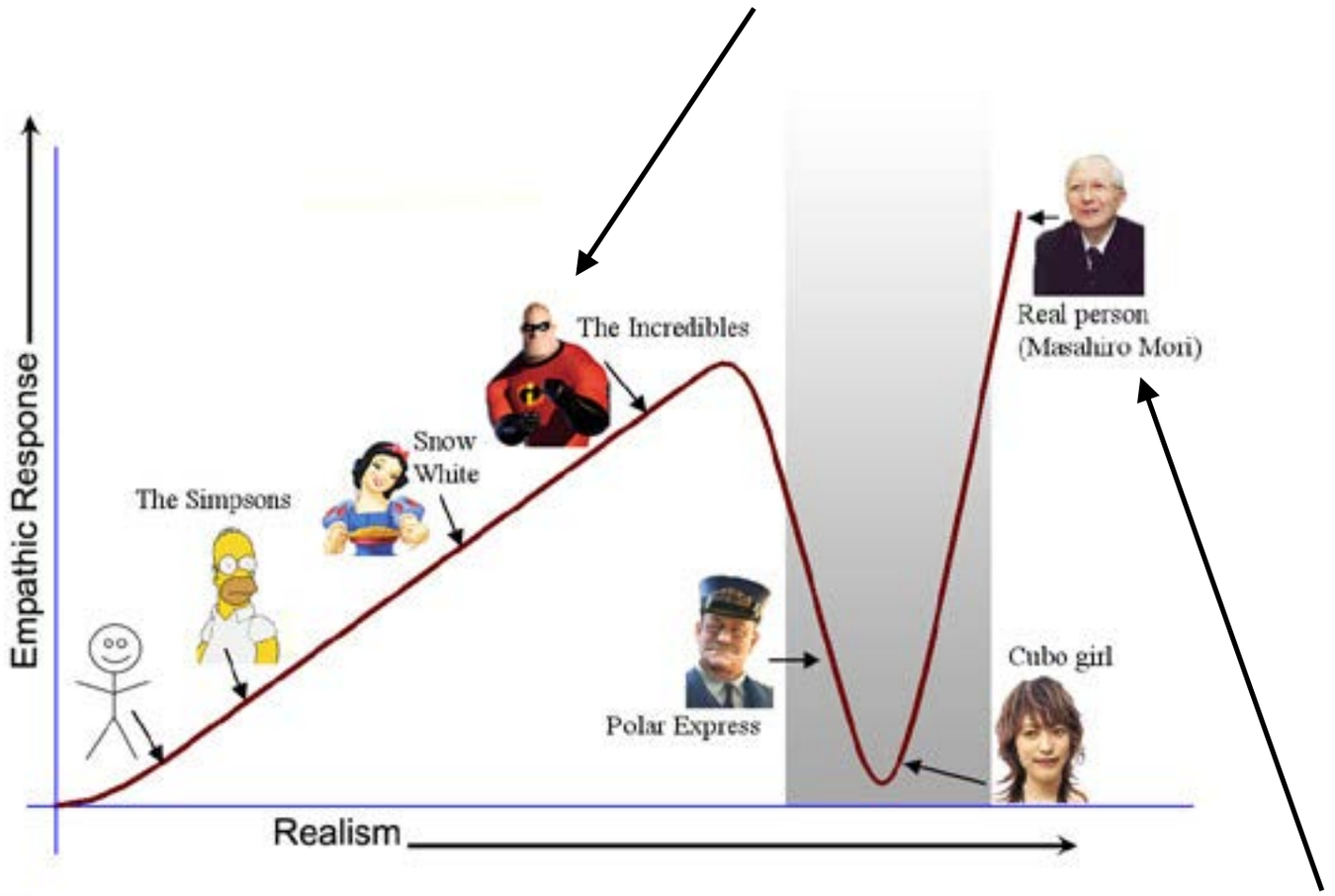
# Emerging Fields



# Goals in Computer Graphics

**Creating a new reality (not necessarily scientific)**

**Practical, aesthetically pleasing, in real time**




**Synthetic images indistinguishable from reality**

**Practical, scientifically sounds, in real time**

# SIGGRAPH & SIGGRAPH Asia

- Main computer graphics event
- Twice a year
- up to 30K attendees
- Academia, industry, artists

ACMSIGGRAPH

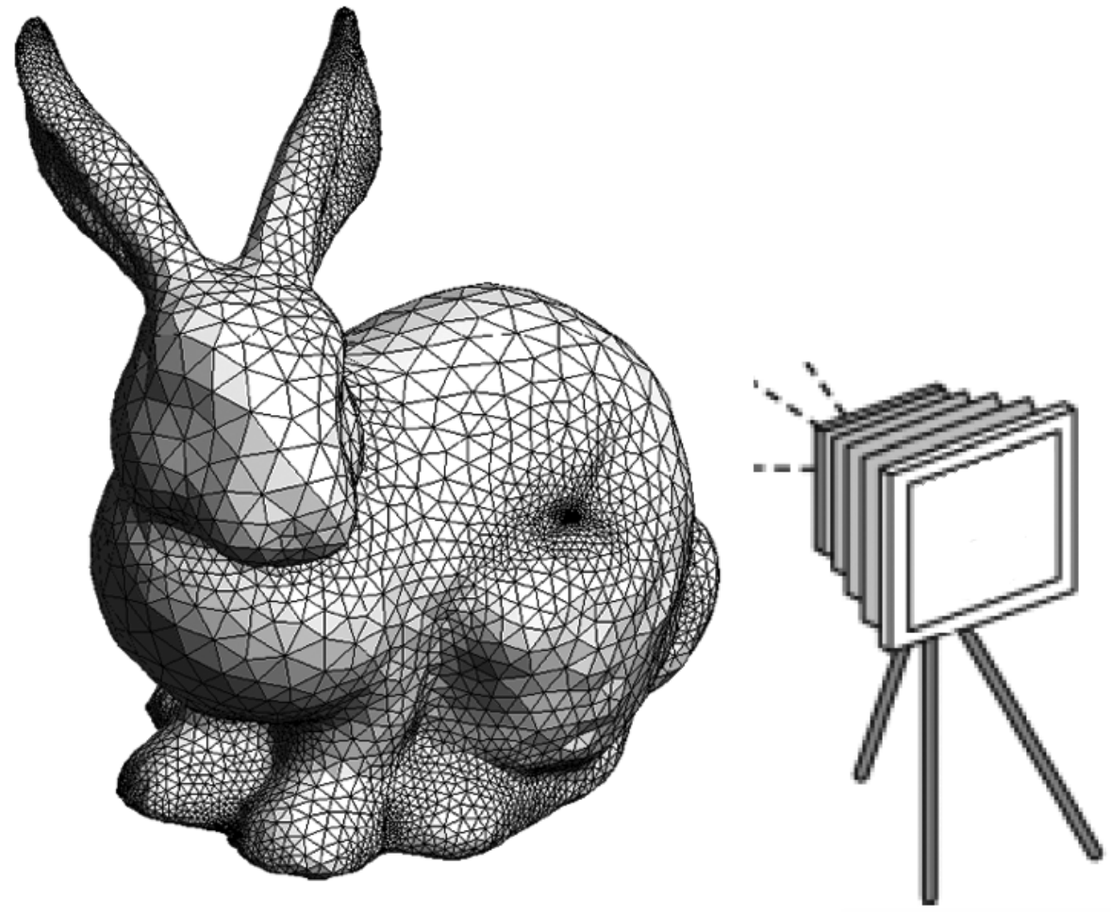
# Course Overview

# 1.1 Introduction

- Graphics@USC
- What is Computer Graphics?
- Administrative Stuff
- Course Overview
- Research Trends

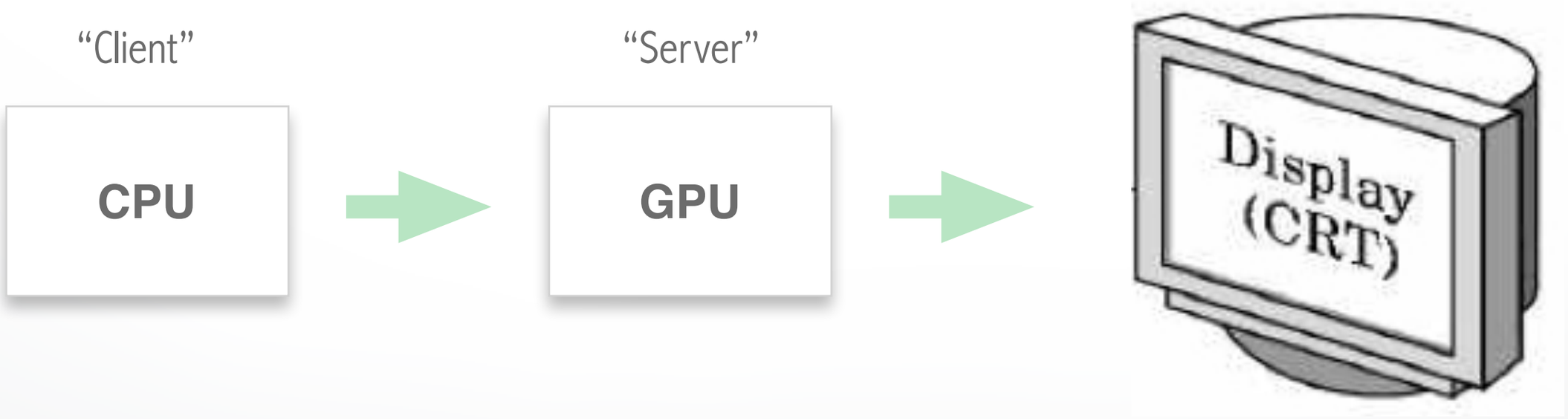
# 1.2 OpenGL Basics

- Primitives and attributes
- Color
- Viewing
- Control functions
- [Angel, Ch. 2]



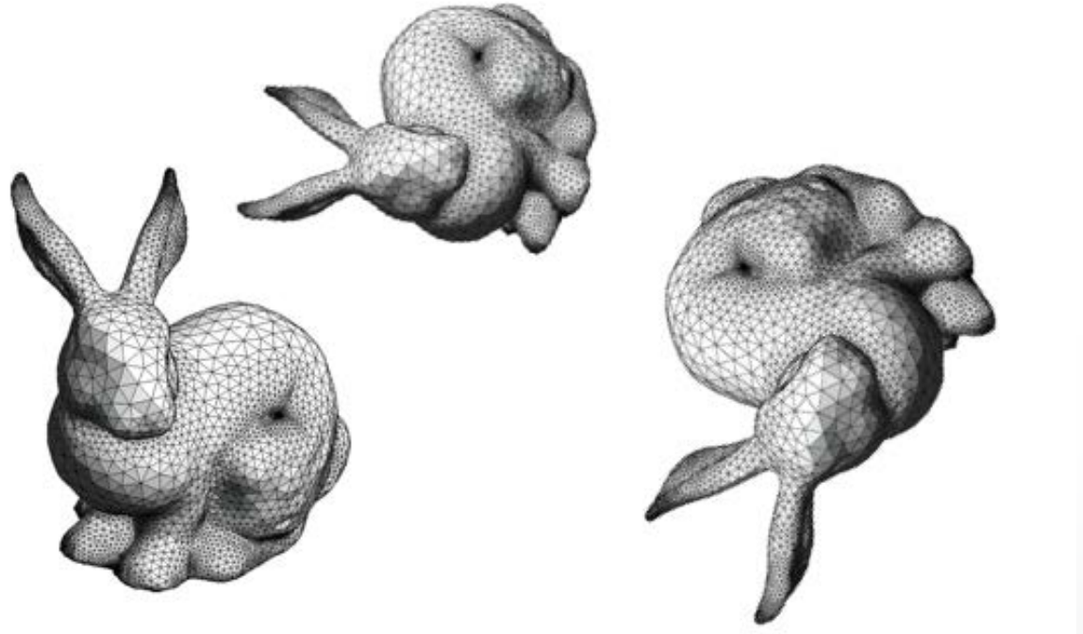
# 2.1 Input & Interaction

- Clients & servers
- Event driven programming
- Text & fonts
- [Angel, Ch. 3]



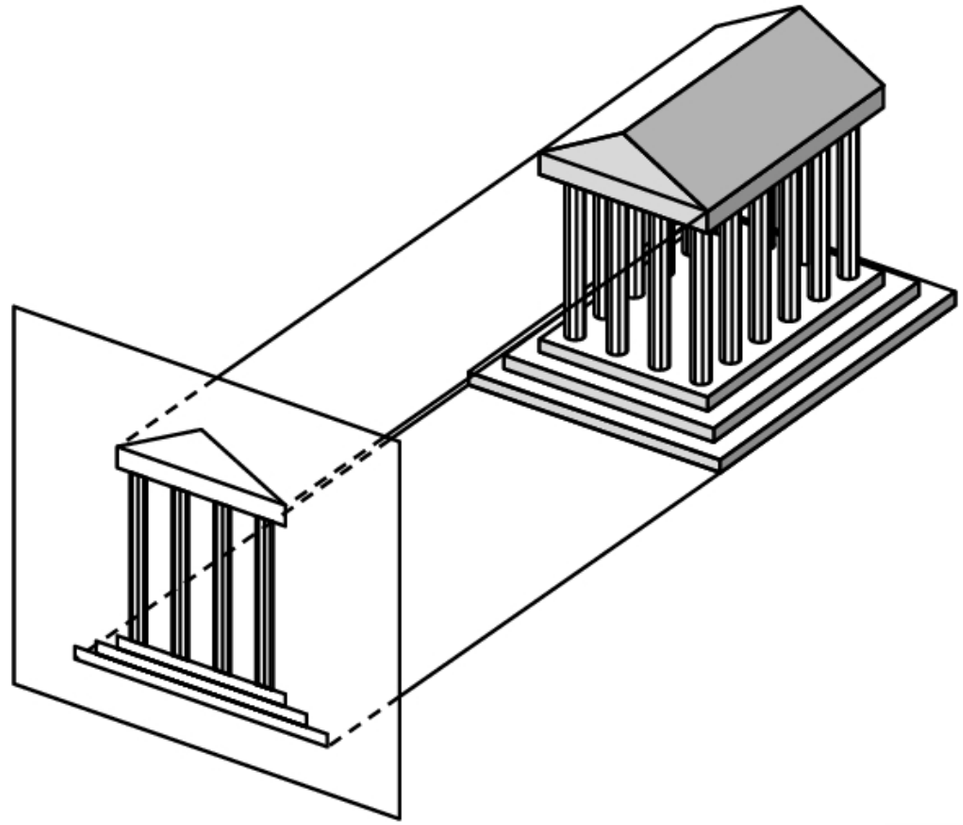
# 2.2 Objects & Transformations

- Linear algebra review
- Coordinate systems and frames
- Rotation, translation, scaling
- Homogenous coordinates
- OpenGL transformations
- [Angel, Ch. 4]



# 3.1 Viewing and Projection

- Orthographic projection
- Perspective projection
- Camera positioning
- Projection in OpenGL
- Hidden surface removal
- [Angel, Ch. 5]

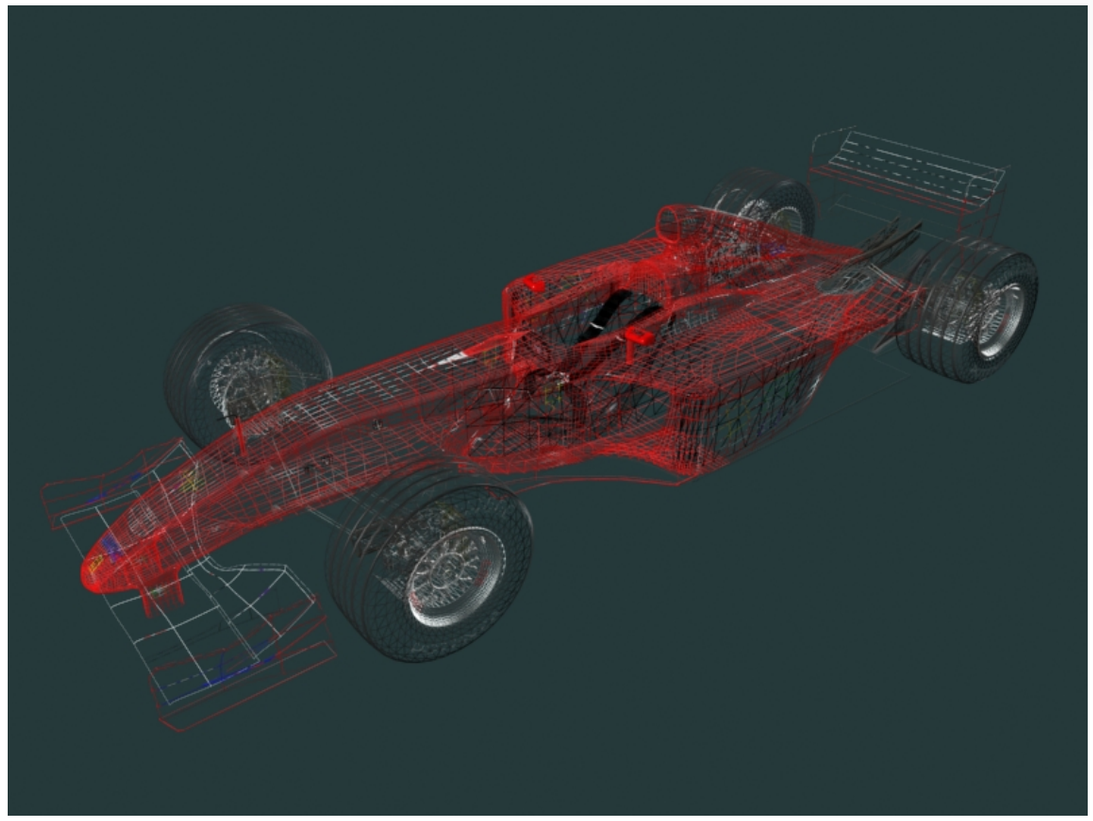


# 3.2 Hierarchical Models

- Re-using objects
- Animations
- OpenGL routines
- Parameters and transformations
- [Angel, Ch. 10]

# 4 Curves & Surfaces

- Recall 3D calculus
- Explicit representation
- Implicit representation
- Parametric curves & surfaces
- Hermite curves and surfaces
- Bézier curves and surfaces
- Splines
- Curves and surfaces in OpenGL
- [Angel, Ch. 12]



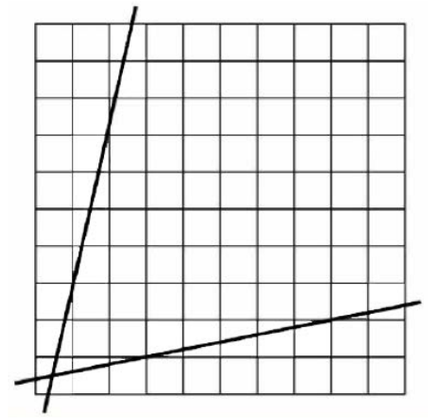
# 5.1 Light & Shading

- Light sources
- Ambient, diffuse, and specular reflection
- Normal vectors
- Material properties in OpenGL
- Radiosity
- [Angel, Ch. 6]

Tobian R. Metoc

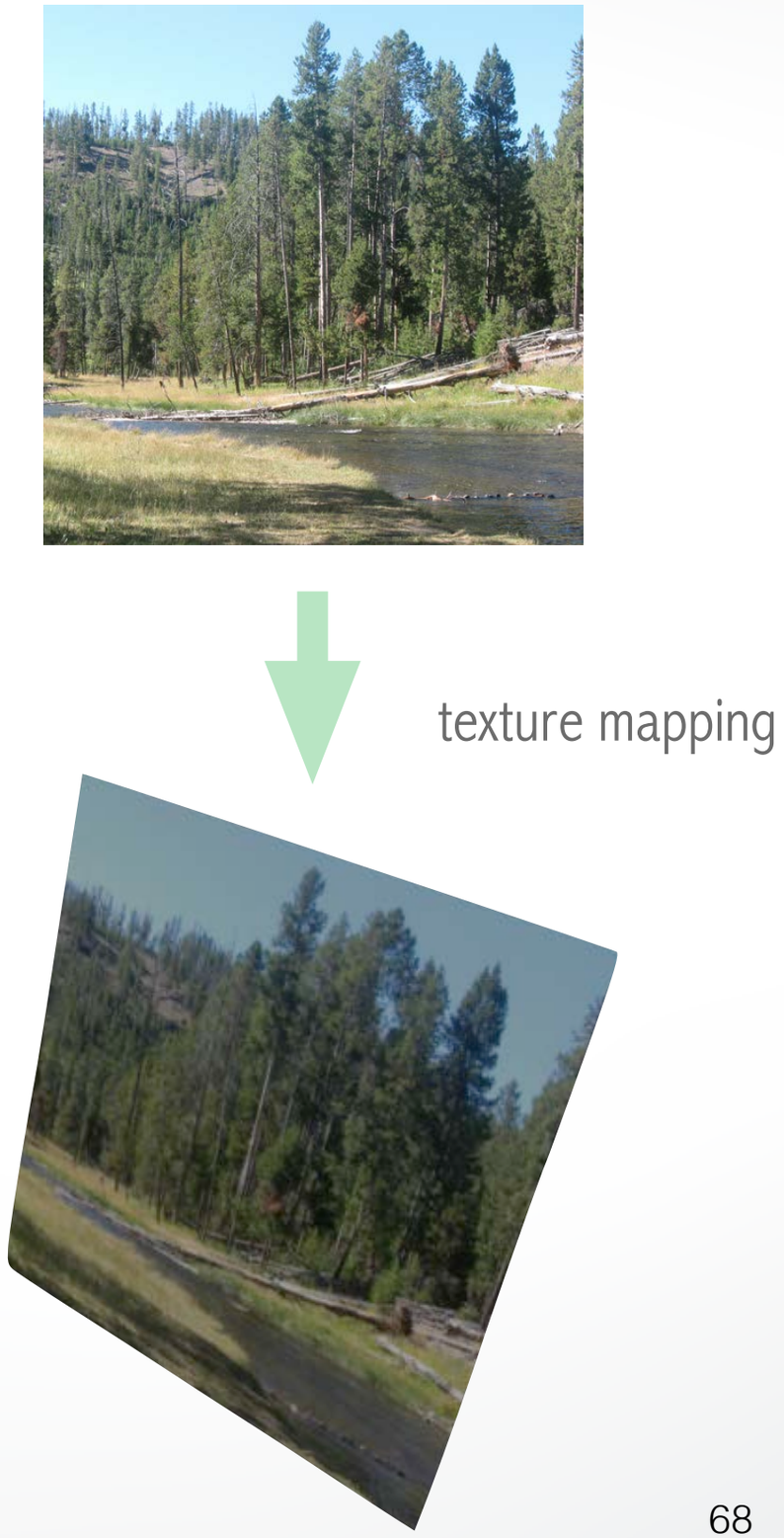
# 5.2 Rendering

- Clipping
- Bounding boxes
- Hidden-surface removal
- Line drawing
- Scan conversion
- Anti-aliasing
- [Angel, Ch. 7,8]



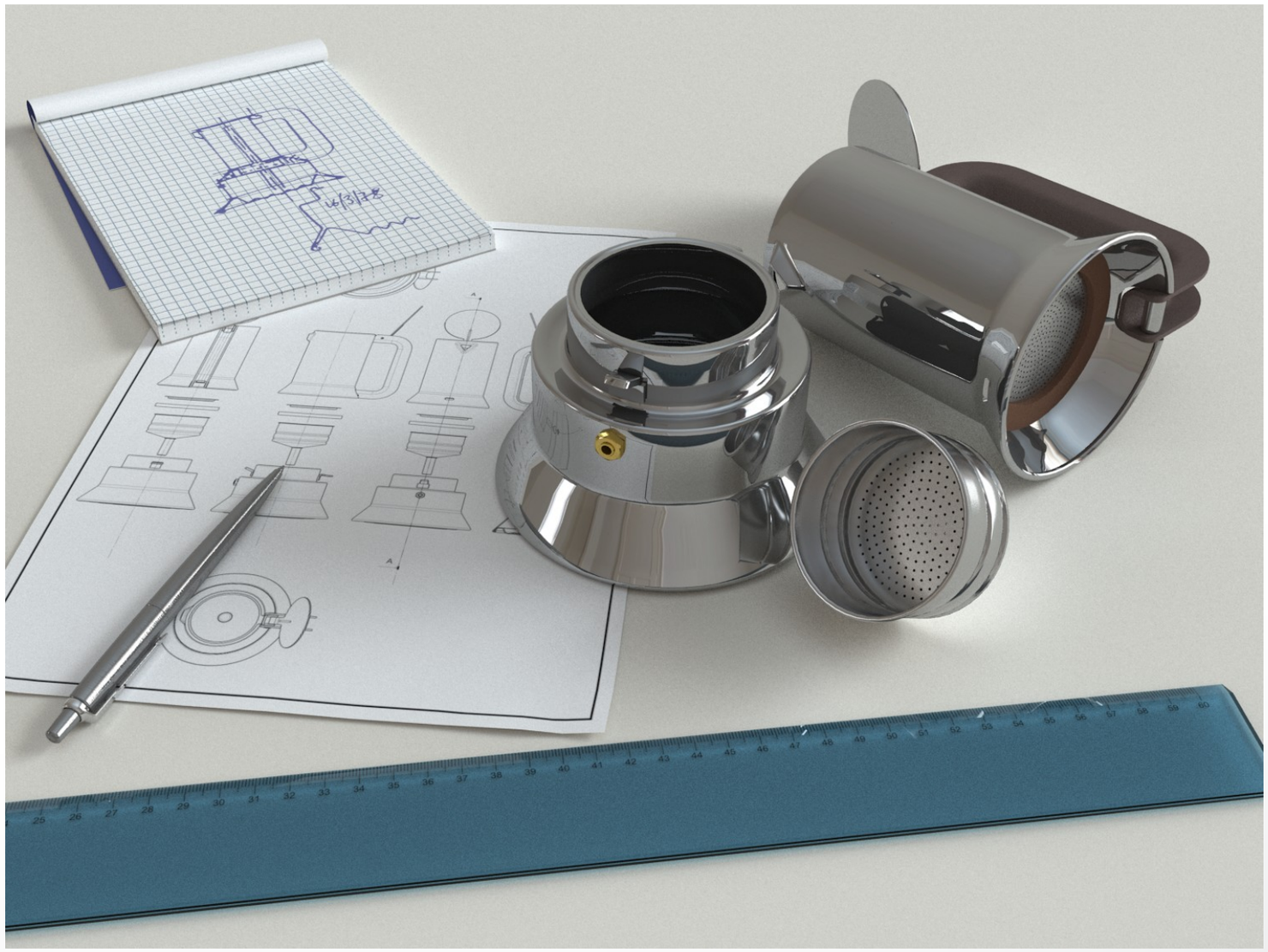
# 6-8 Textures and Pixels

- Texture mapping
- OpenGL texture primitives
- Bump maps
- Environment maps
- Opacity and blending
- Image filtering
- [Angel, Ch. 8]



# 9-10 Ray Tracing

- Basic ray tracing [Angel, Ch. 13]
- Spatial data structures [Angel, Ch. 10]
- Motion blur
- Soft shadows



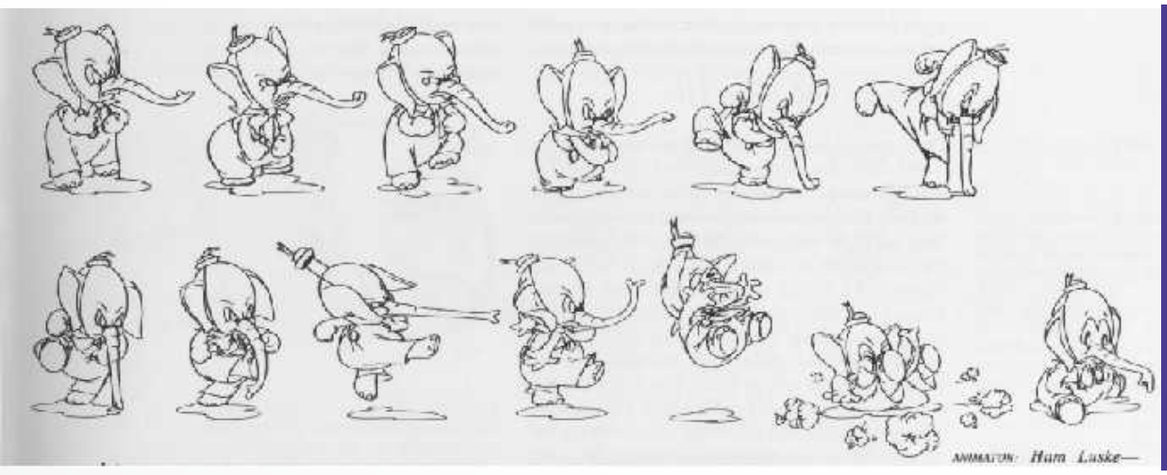
www.yafaray.org

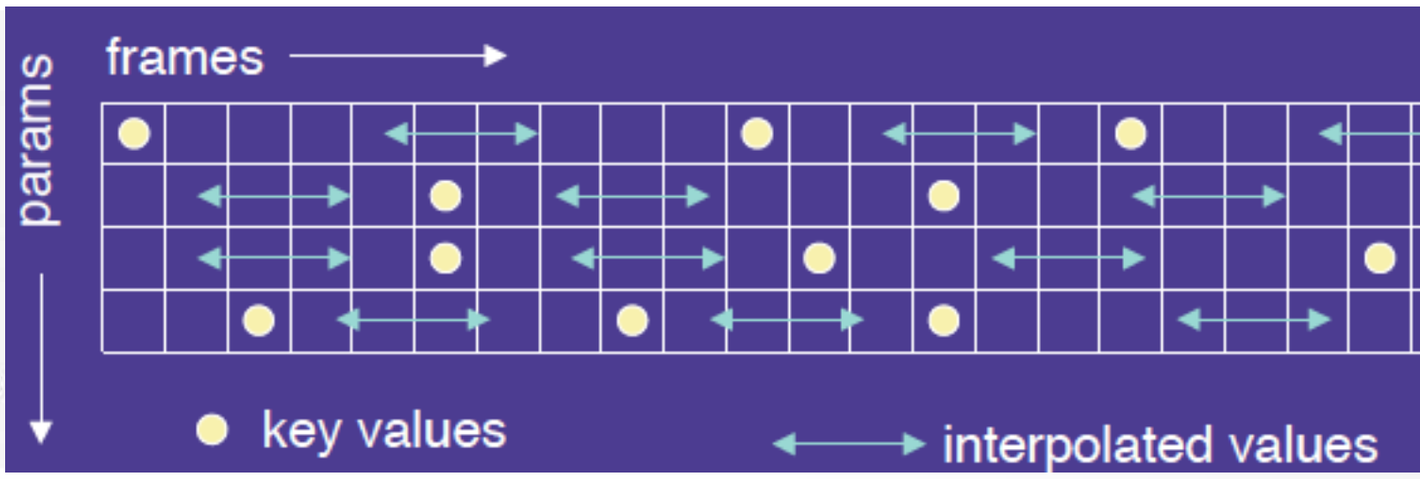
# 11.1 Radiosity

- Local vs global illumination
- Interreflections
- Radiosity equation
- Solution methods
- [Angel Ch. 13.4-5]

# 11.2 Animation

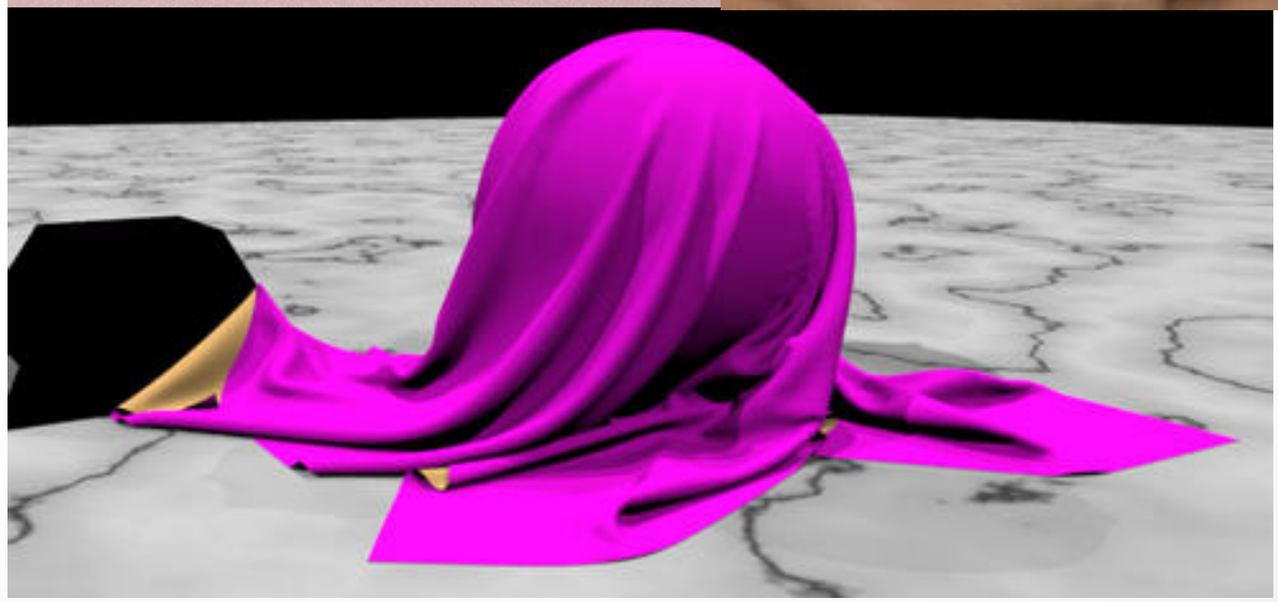
- Traditional Animation
- Keyframe Animation
- Computer Animation





# 12 Physically Based Models

- Particle systems
- Spring forces
- Cloth
- Collisions
- Constraints
- Fractals
- [Angel, Ch. 11]

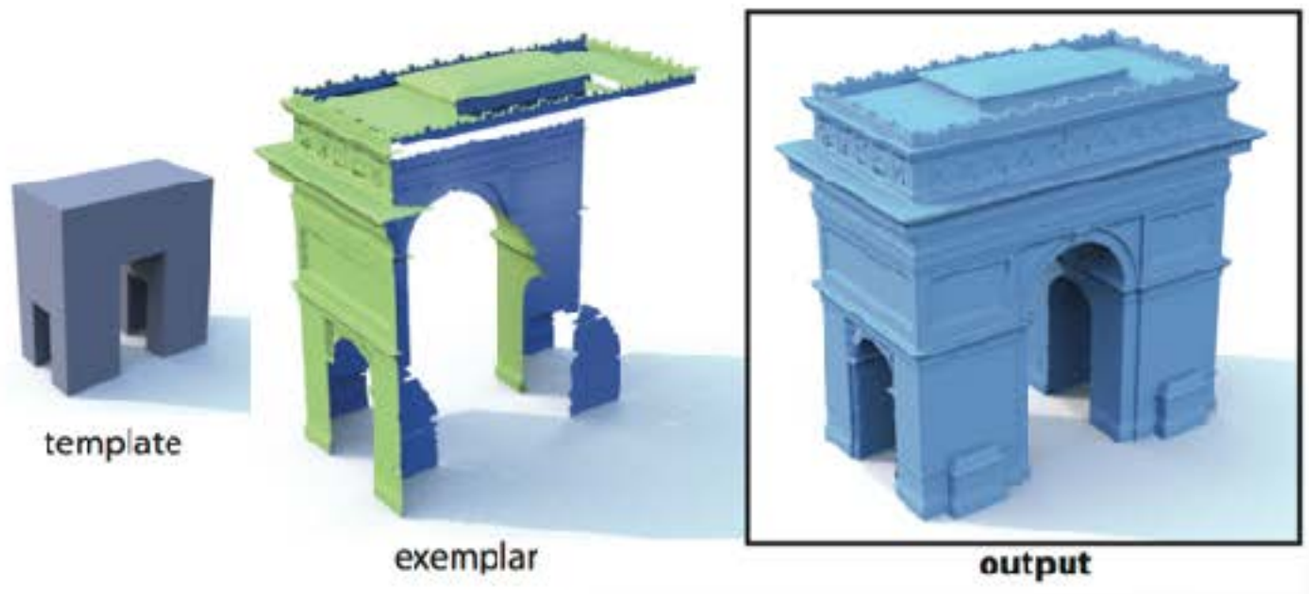


# 13 Image Processing

- Blending
- Display Color Models
- Filters
- Dithering
- [Angel, Ch 7-8]

# 14-15 Guest & “Wildcard” Lectures

- Realtime 3D Reconstruction
- Geometry Processing
- Graphics & Machine Learning
- Data-Driven Modeling
- . . .

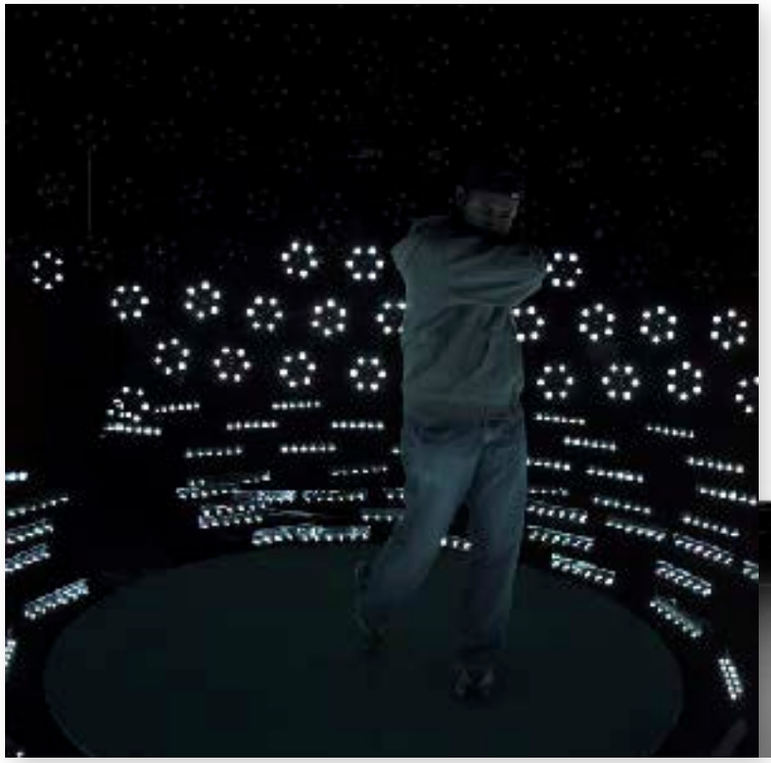


# Research Trends

# From Offline to Realtime

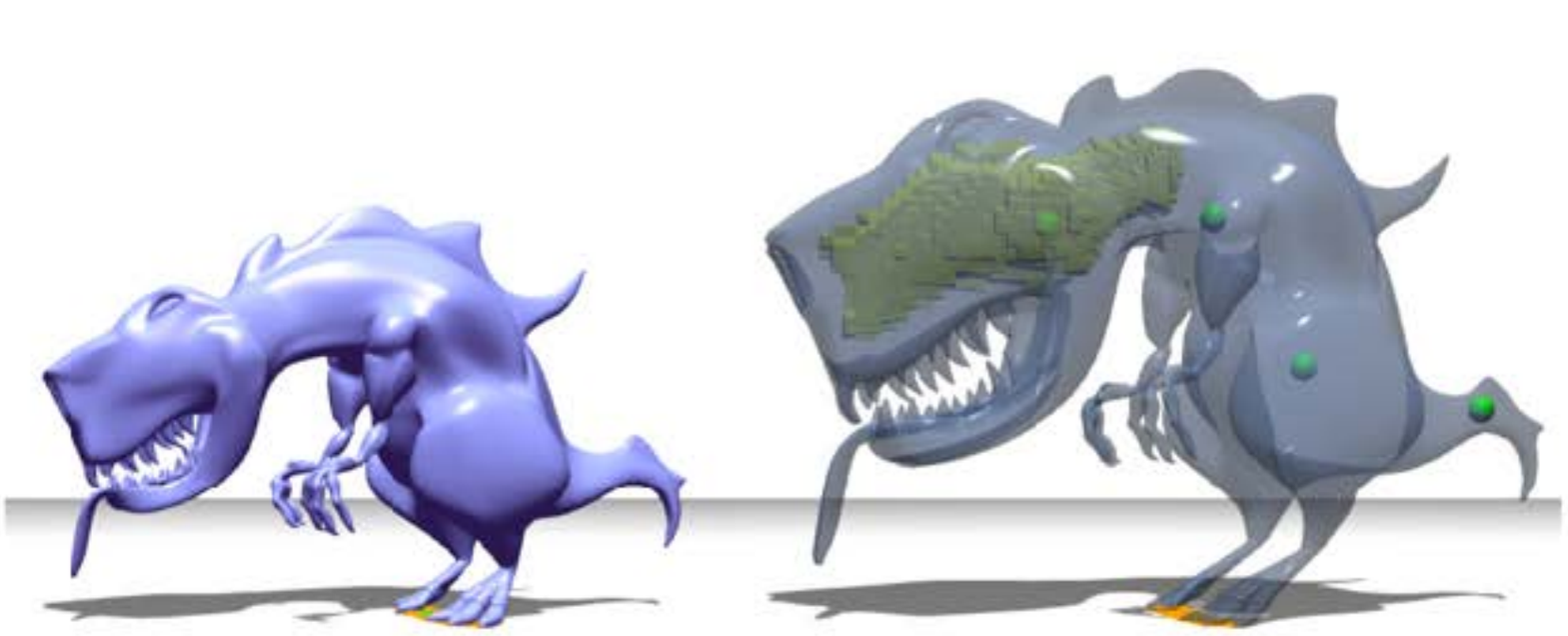
# From Graphics to Vision

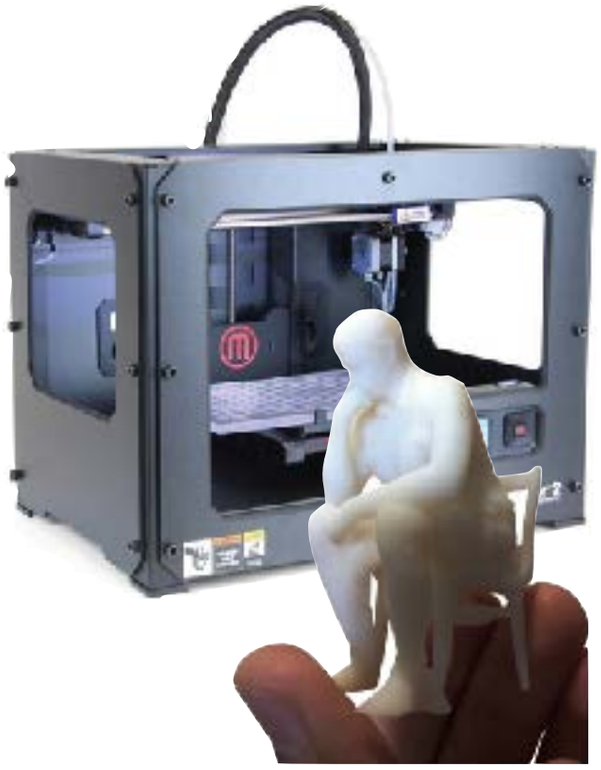
[Newcombe et al. ’11]
KinectFusion



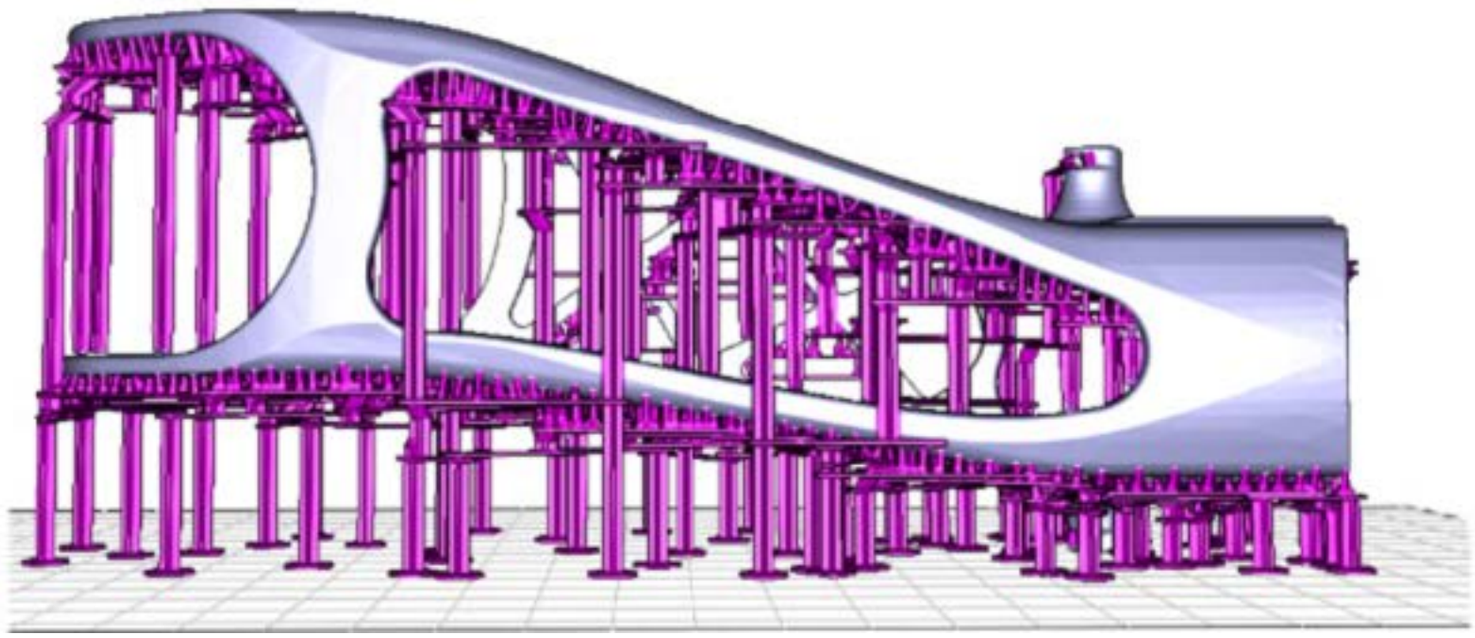
multi-view photometric stereo

# From Graphics to Fabrication





3D printing



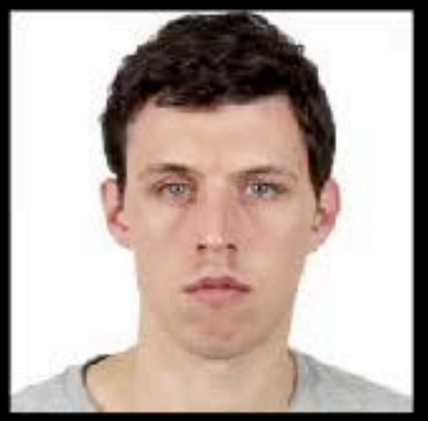
# From Production to Consumers

VFX

online shopping

# AI-Driven Computer Grahpics

source video



input image

subject A

subject B

subject C

our result

# Acknowledgements

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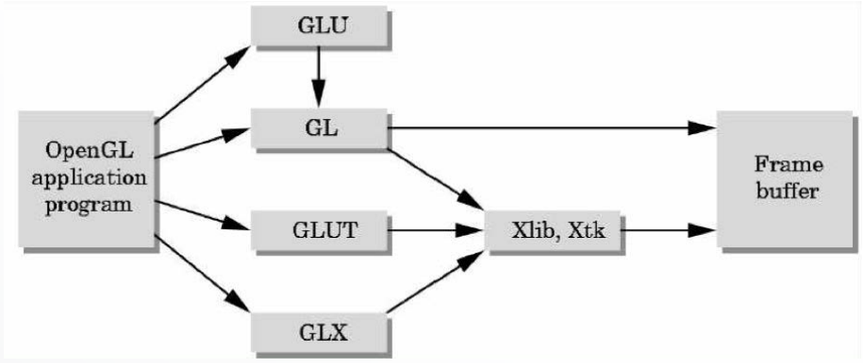
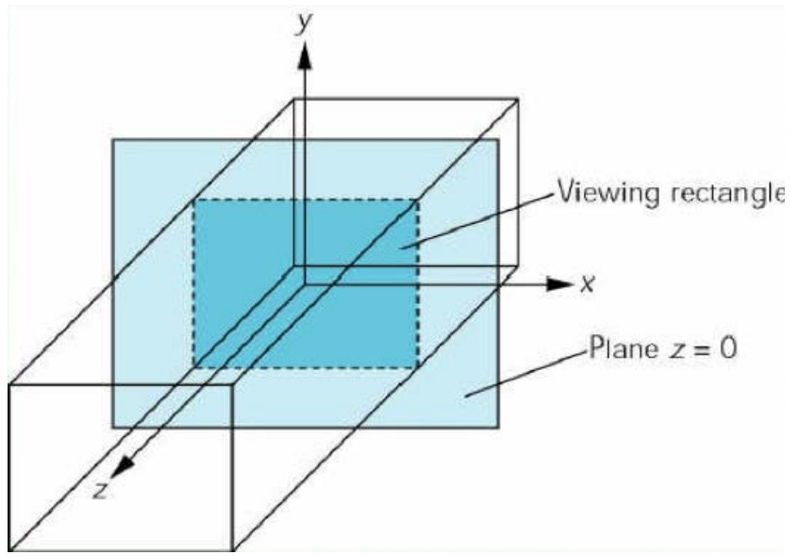
- Justin Solomon, Stanford/Princeton/MIT
- Cornell, MIT, UC Berkeley, …

# Next Time

- Basic Graphics Programming
- OpenGL Pipeline





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# Thanks!