

GAMES 103: Intro to Physics-Based Animation

Instructor:	Huamin Wang (games103@style3D.com)
Website:	http://games-cn.org/games103
Meeting:	Monday 4:00PM to 5:30PM
Length:	12 Weeks
Q&A:	Monday 5:30PM to 6:00PM
Grader:	...
Prerequisites:	Linear algebra, calculus, programming skills

Course exchange Wechat group
(Join by scanning Wechat QR Code)



More About Prerequisites

- The course is designed for
 - Undergraduates in the 3rd or 4th year, or fresh graduates.
- Linear Algebra
 - You Should know basic linear algebra concepts, such as vectors, matrices, linear systems, SVD...
- Calculus
 - You should know how to calculate basic derivatives and integrals; you should understand chain rules, gradients, etc.
- Programming Skills
 - C, or C++, or C#, or Javascript
- Ready to learn by yourself
- The life will be much easier if you took
 - Numerical methods (numerical linear algebra, numerical PDEs), finite element analysis, fluid dynamics...

Tentative Syllabus

Days	Topics	Assignments	
Day 1	11/1/2021	Introduction	
Day 2	11/8/2021	Math Background	
Day 3	11/15/2021	Rigid Body Dynamics	
Day 4	11/22/2021	Rigid Body Contacts	HW 1
Day 5	11/29/2021	Mass-Spring Systems	
Day 6	12/6/2021	Position-Based Dynamics, Projective Dynamics and more	HW 2
Day 7	12/13/2021	Collision Handling of Cloth	
Day 8	12/20/2021	Soft Body Dynamics and Finite Element Method I	HW 3
Day 9	12/27/2021	Soft Body Dynamics and Finite Element Method II	
Day 10	1/3/2021	Waves	HW 4
Day 11	1/10/2021	Incompressible Fluid Dynamics and Eulerian Fluids	
Day 12	1/17/2021	SPH and Position-Based Fluids	

NO Exam!

No textbook, but a lot of suggested readings.

Readings help you pick up insights missing from class.





Products

Solutions

Learning

Support & Services

Community

Developer tools

Get started



MORE THAN AN ENGINE

Create and grow more with Unity

Unity is the leading video game engine – and so much more. Discover solutions to help you at every stage of the game development lifecycle, from big idea to big success.

[Create with Unity Pro](#)[Explore solutions](#)

It's official: Parsec joins Unity in acquisition deal [Learn more](#)

Real-time solutions, endless opportunities

Games

Everything you need to create and operate your games.

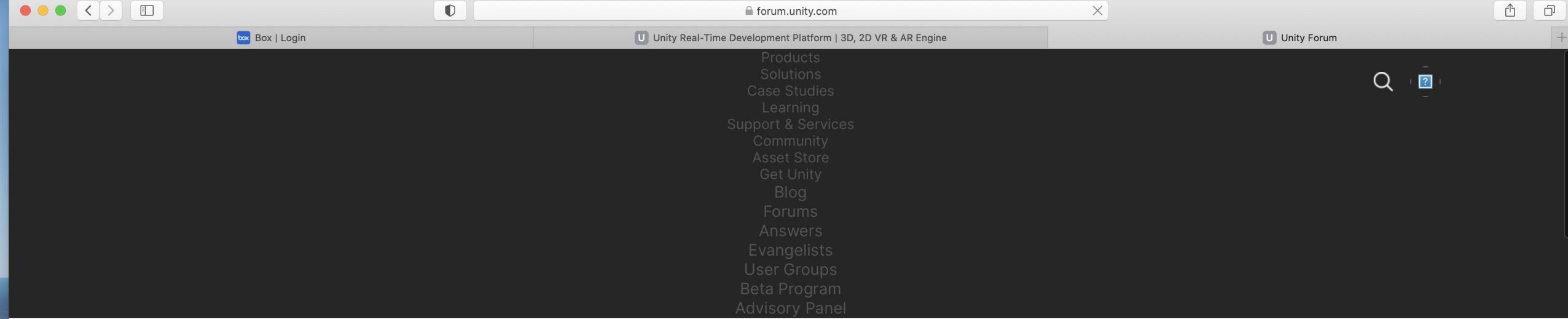


Automotive, Transportation & Manufacturing

Film, Animation & Cinematics

Unprecedented artistic freedom and faster

Architecture, Engineering & Construction



Forums

Search Forums Recent Posts

Welcome to the Unity Forums



Announcements

Current LTS Version: 2020.3
Unite Now



Getting Started

Getting acquainted with Unity? This is the place for you! Check out the Learn section and the Documentation



Teaching & Certification

Discuss the Learn content and Unity Certification.
Teaching | Unity Certification



Betas & Experimental Features

2021.2 Beta | 2022.1 Alpha | Packages |
DOTS | Tiny | Linux Editor

Unity Community Discussion



2D

Discussions all about 2D features in Unity
Docs | Learn



AR/VR (XR) Discussion

All things XR.
AR | VR | XR Interaction Toolkit and Input |
Unity MARS



Audio & Video

Audio Docs | Learn Audio | Video Docs |
Recorder



Animation

Get help with everything animation.
Docs | Learn



Sign up



Unit test



The goal is to use Unity for learning, NOT to learn Unity.

What you need to succeed...

- Get prepared (prerequisites, Unity, etc.)
- Attend meetings, or watch the replay
- Finish supplemental readings
- Do HWs
 - No need fancy graphics card. Your laptop should suffice.
- Read more, write more, think more...

Issues for Discussion Today

- What's computer graphics?
- What's computer graphics used for?
- What's physics-based animation?
- What are the topics to be studied in this class?

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What's Computer Graphics?

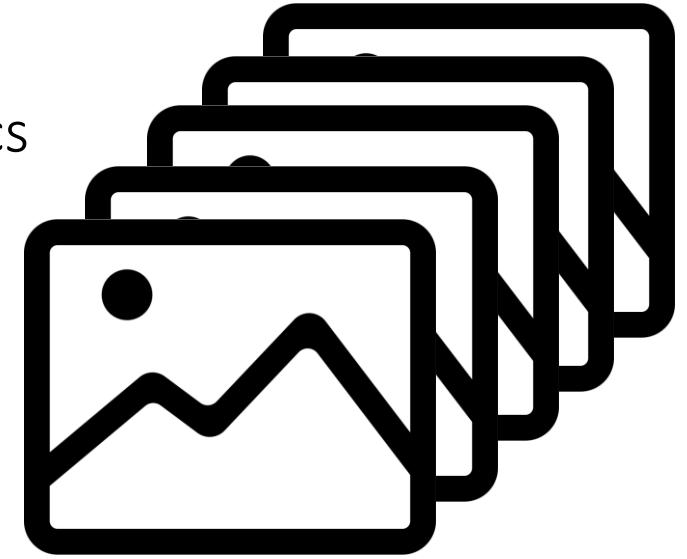


3D Digital World

Computer Graphics

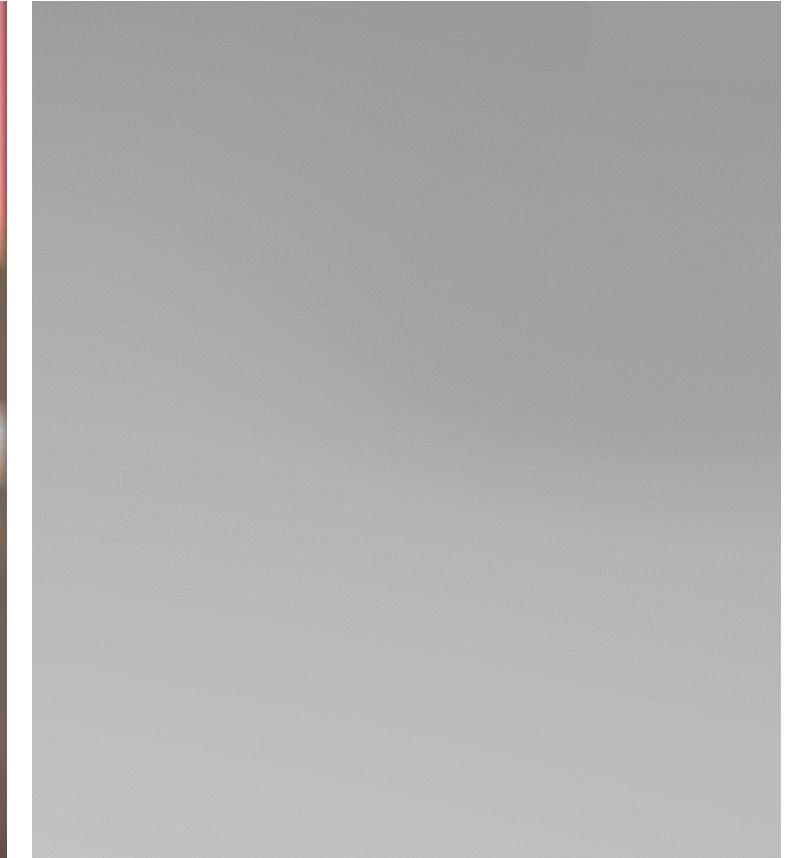
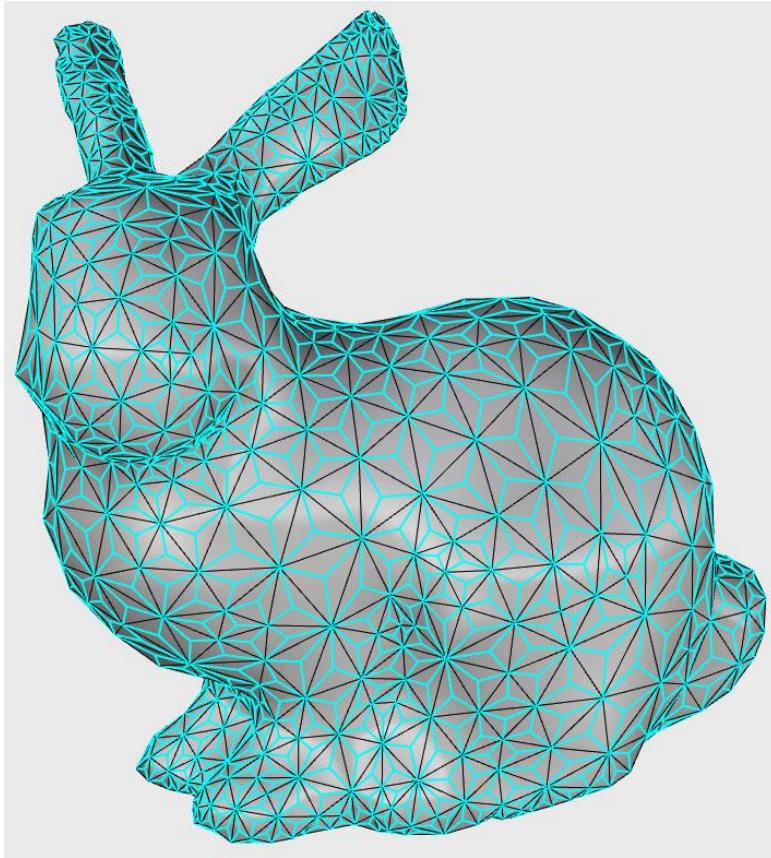


Computer Vision



2D Digital Images

Computer Graphics Areas



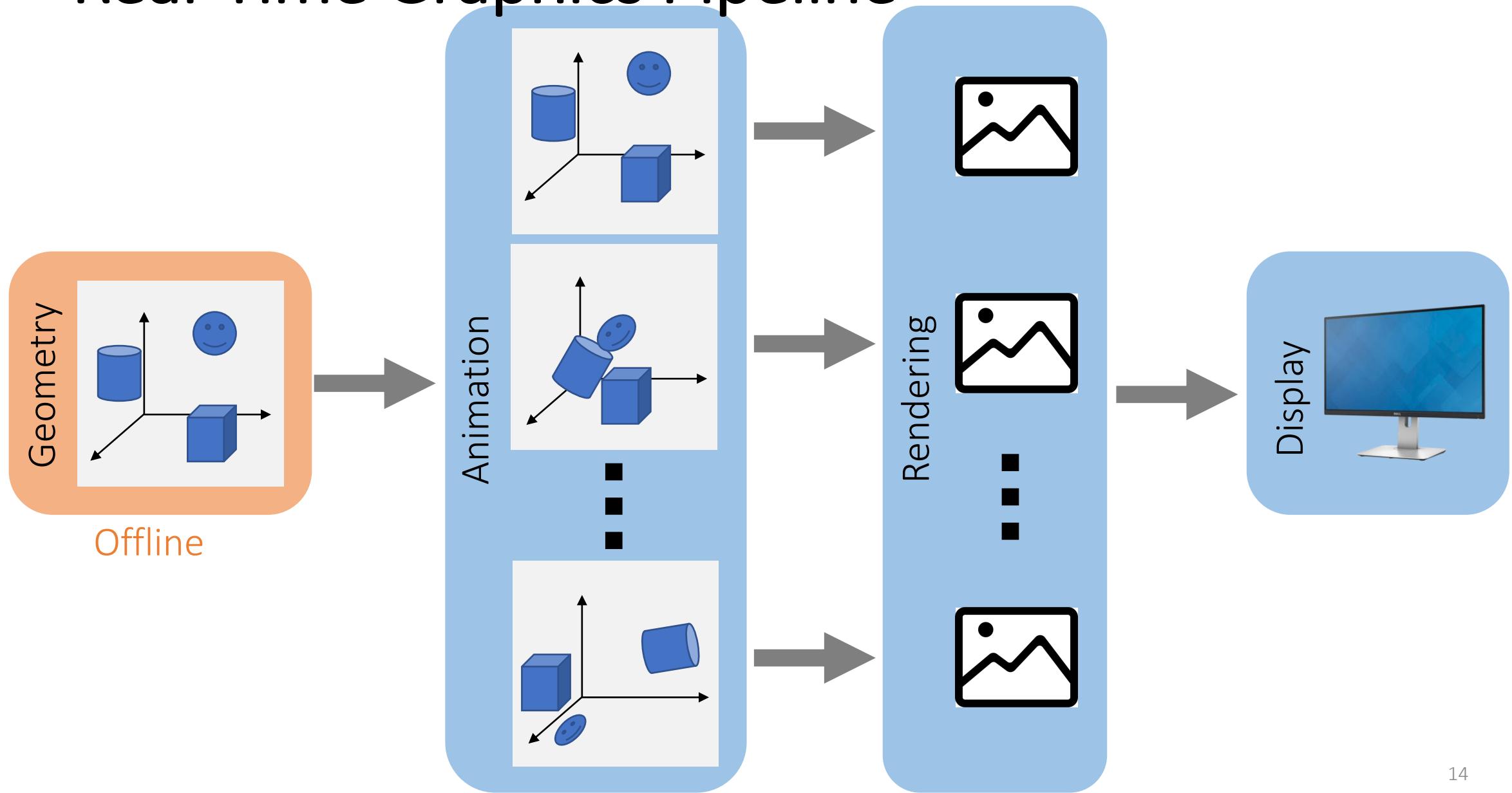
Geometry: Modeling the 3D world

Rendering: Visualize the 3D world

Animation: Animate the 3D world

Stanford Bunny: the de facto standard model for graphics research, created by Greg Turk in 1994 at Stanford.
<http://graphics.stanford.edu/data/3Dscanrep/>

Real-Time Graphics Pipeline



The number of frames sent to display in a second is called the *frame rate*.

For example, 24 FPS, 30 FPS, 60 FPS, ...

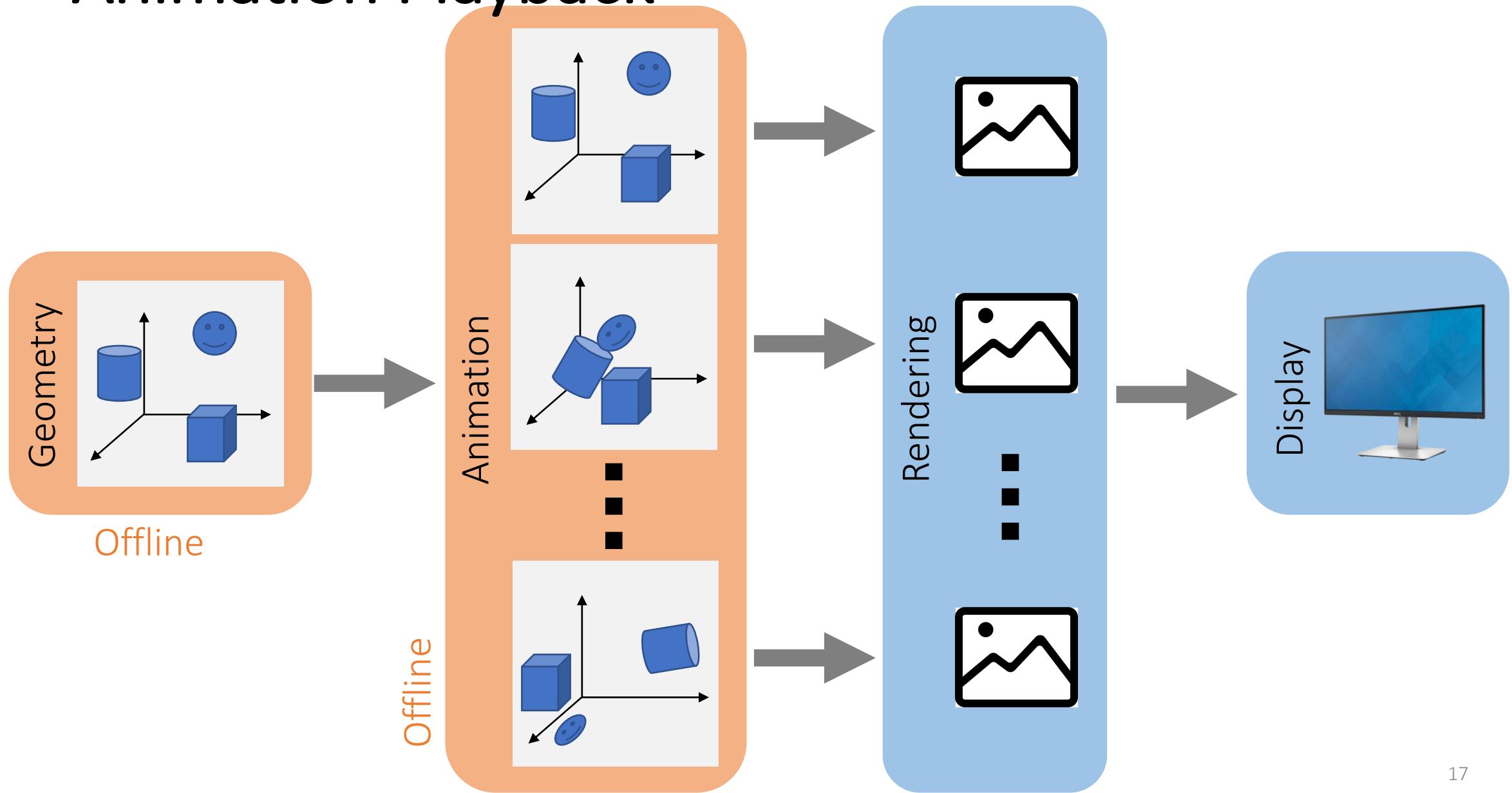


Unfortunately, real-time graphics (real-time animation + real-time rendering) is challenging.

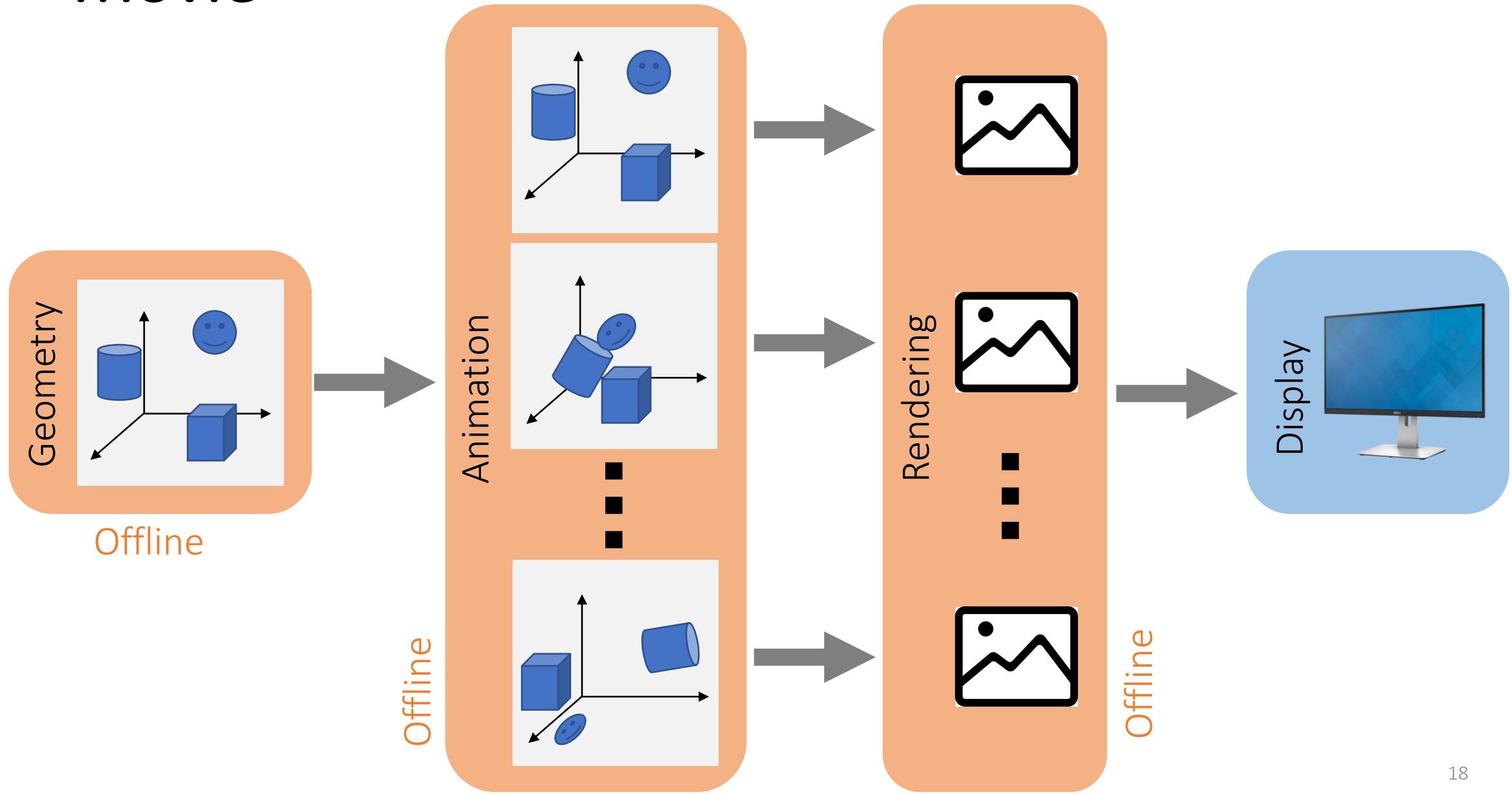
Without real-time graphics, graphics applications are narrowly limited...



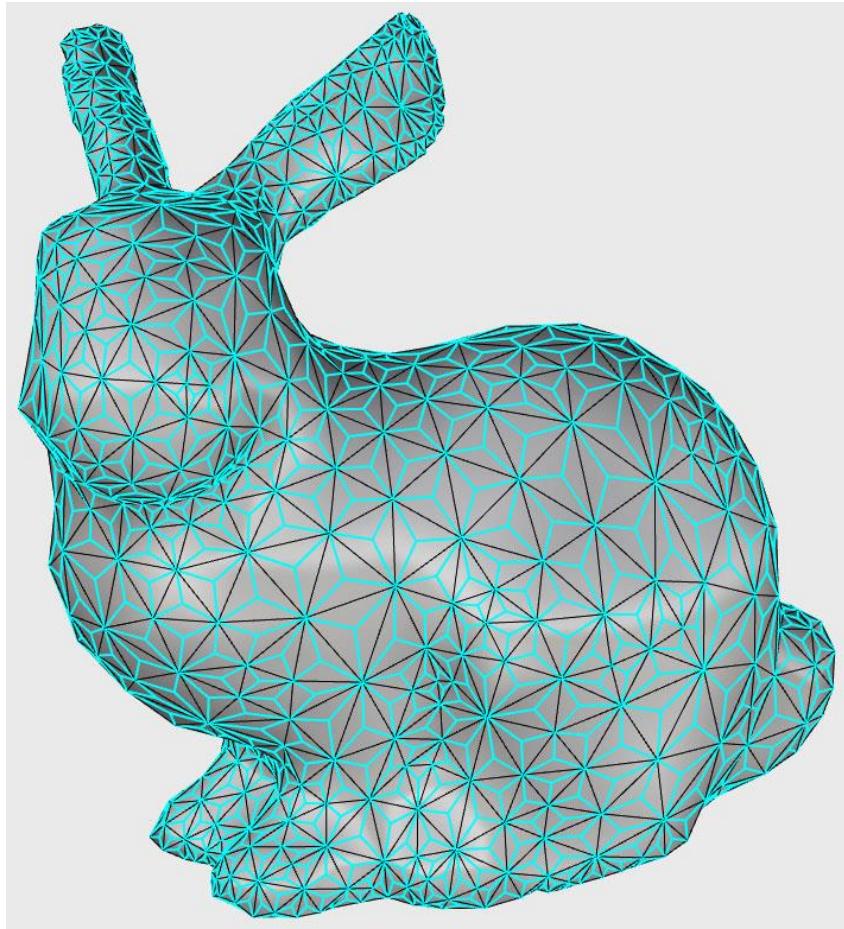
Animation Playback



Movie



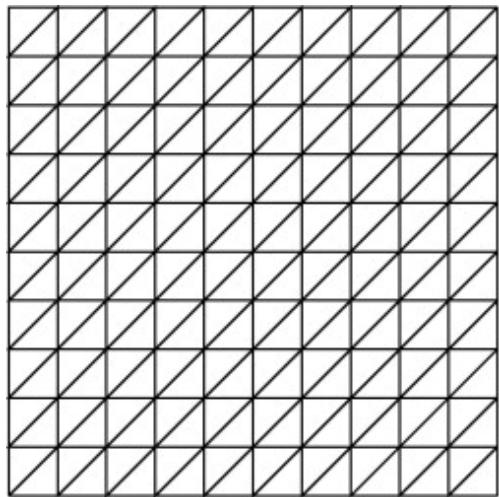
Geometry: Three Representations



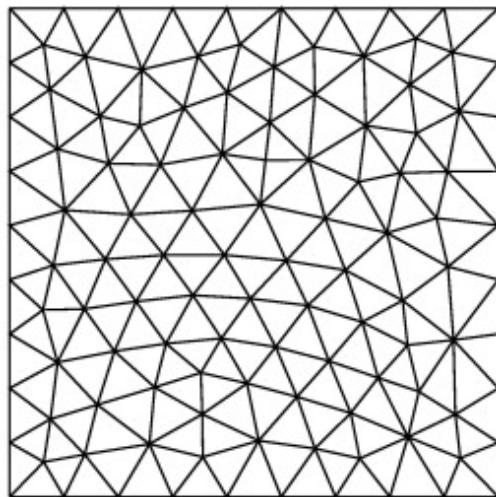
Mesh

- A mesh contains:
 - Vertices (nodes)
 - Elements (triangles, polygons, tetrahedra...)
- Triangle mesh is the foundation of graphics.
- Problems:
 - Meshing (Delaunay triangulation)
 - Simplification/subdivision
 - Mesh optimization (smoothing, flows...)
 - Volume mesh

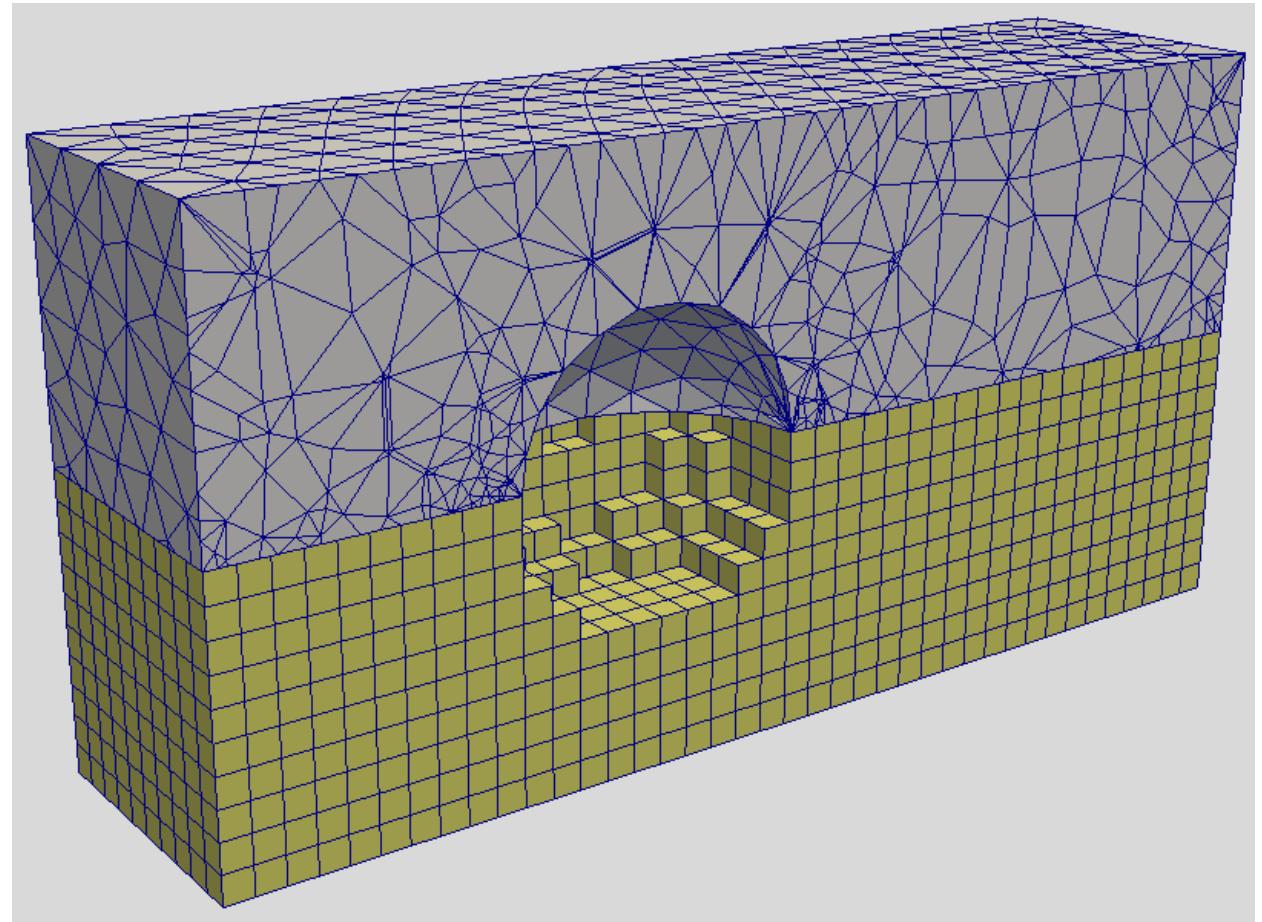
Geometry: Three Representations



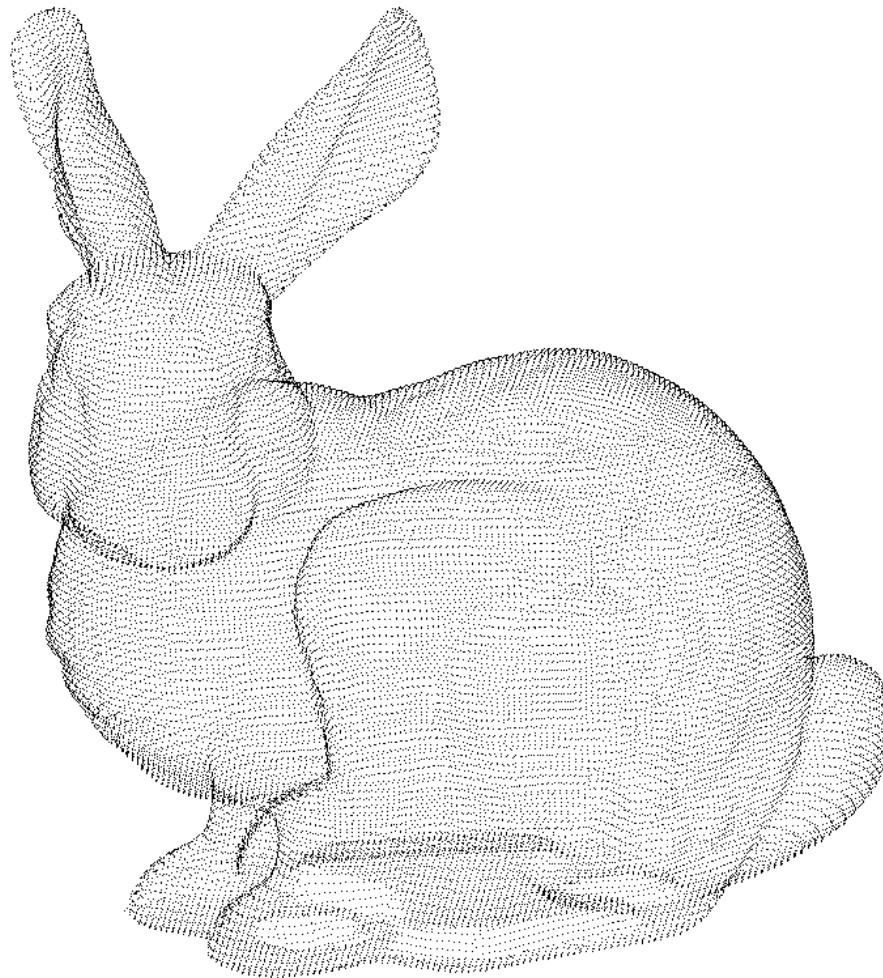
Structured Mesh



Unstructured Mesh



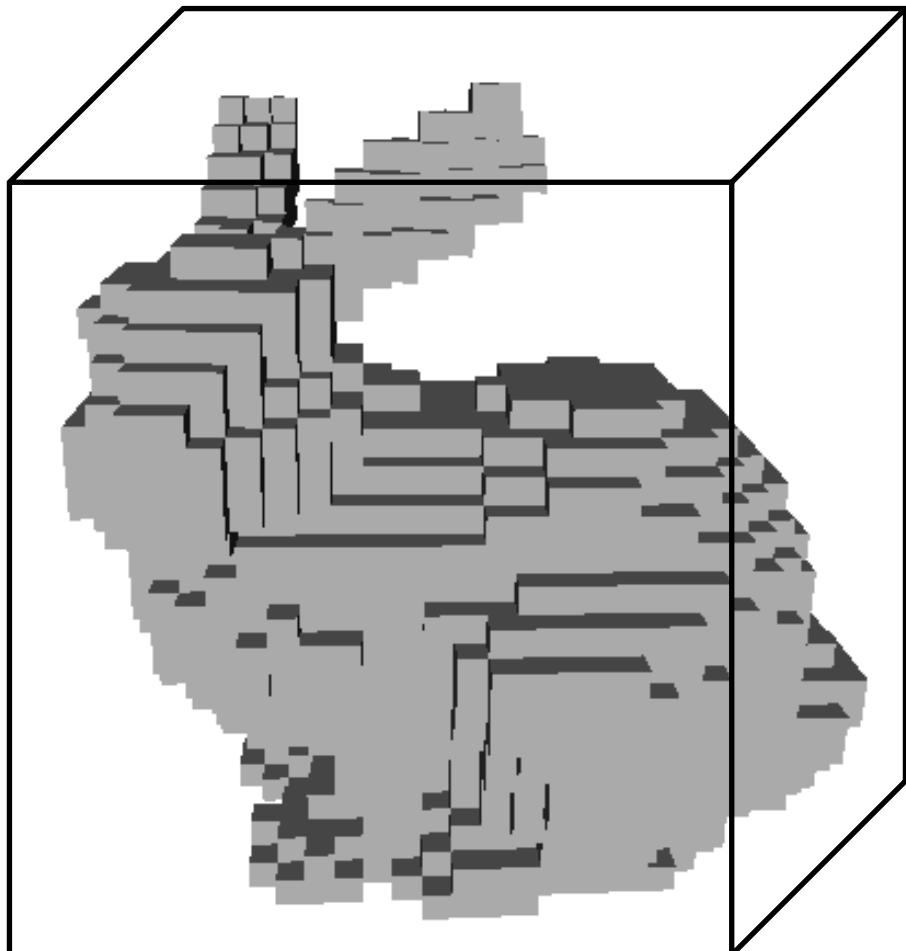
Geometry: Three Representations



Point Cloud

- A point cloud is simple.
- It can be raw data from surface scan.
- Problems:
 - Mesh reconstruction from cloud
 - (Re)-Sampling
 - Neighborhood search
 - ...

Geometry: Three Representations



Volumetric Grid

- A grid partitions the space; a cell stores the physical quantities at that spot.
- Don't confuse it with structured mesh.
- It's often acquired from volumetric scan, e.g., CT.
- Problems:
 - Memory cost (octree?)
 - Volumetric rendering?
 - ...

Rendering: Non-Photorealistic vs. Photorealistic



Non-Photorealistic



Photorealistic

1/8 ★ JOGADORES NECESSÁRIOS PARA INICIAR 0/8

2/8 ★ JOGADORES NECESSÁRIOS PARA INICIAR 2/8

RTX OFF

RTX ON

Rendering: Material Scan

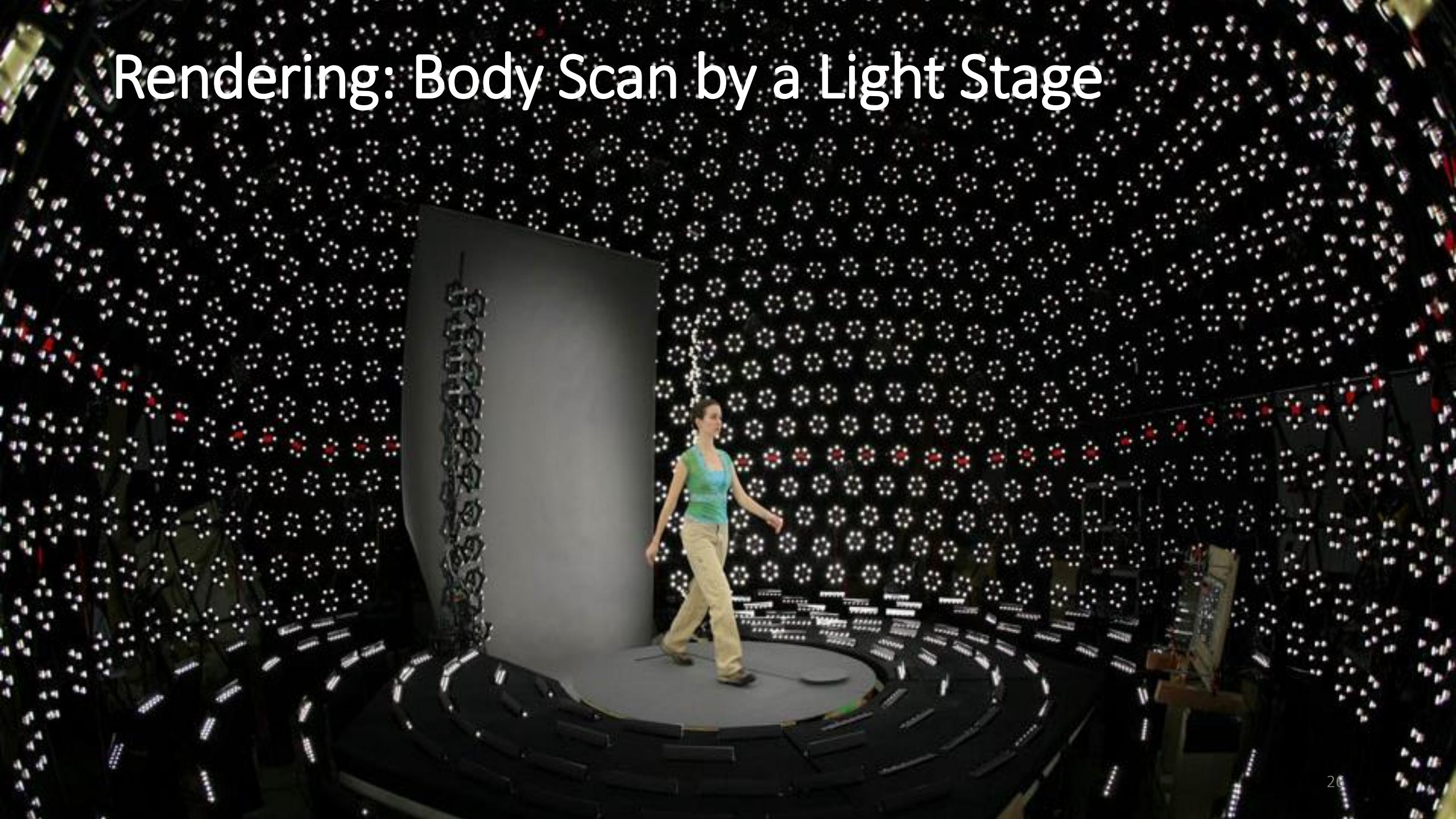
photo



VRscan



Rendering: Body Scan by a Light Stage



Character and Physics-Based Animation



Character Animation



Physics-Based Animation

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Computer Graphics for Entertainment



Games



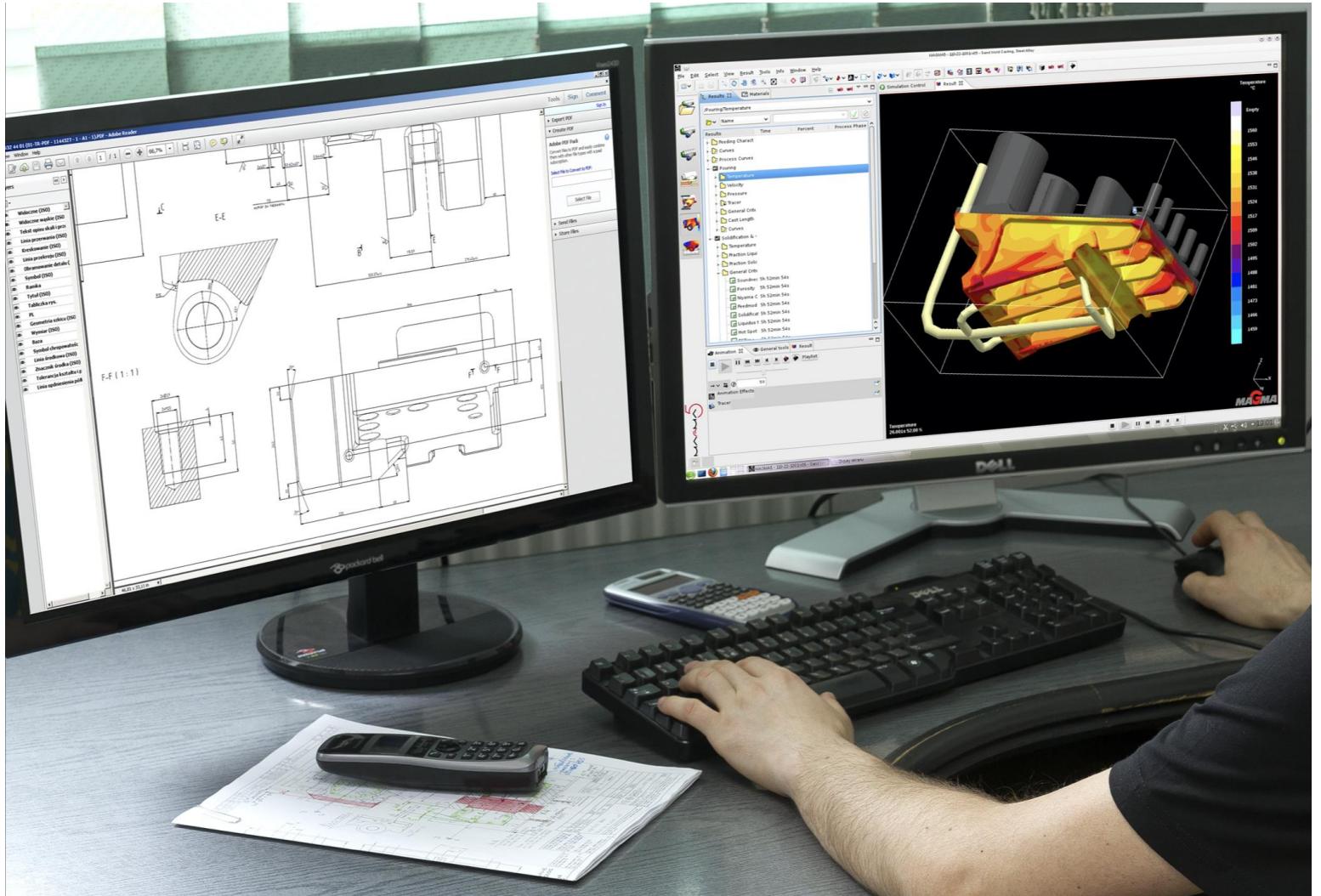
Special Effects



Social Media

Computer Graphics for Design

- Mechanics
- Architecture
- Art
- Fashion
- and more...



文件 开始 版片 素材 测量 显示 设置

冲锋衣三合一

Hello, 建模 2D

选择/移动 编辑版片 编辑缝纫 线缝纫 自由缝纫 编辑假缝 添加假缝 模特圆周胶带 归拔 重置2D 折叠安排 固定针 设定层次 模拟

选择版片进行平移、旋转、缩放等操作 点击查看更多

场景 素材 尺寸 记录

当前服装 素材库

织物 阳离子 里子黑 黑色网 织物1 毛 刺 img13 灰色摇 织物2 edging

图案 头孔 后领标 work\01 02 03 后领标 work\ 默认图

扣眼 默认组

拉链 腋下 插兜 胸 帽子 前门 前门 里胸兜 默认拉

明线 明线1 双桔 0.1黑色 0黑色 0.5黑 2.5黑 0橘色 反面 0.1黑

褶皱

2D版片视窗

3D服装视窗

属性

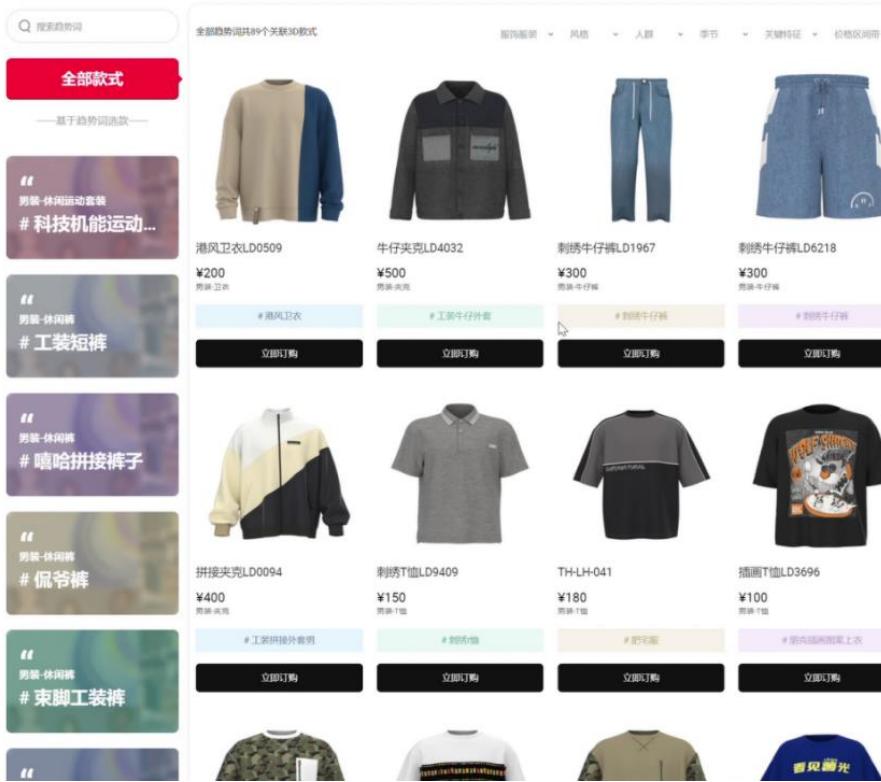
类型
名字
启用
阴影
产生反射
强度
颜色
形状
宽度(mm)
高度(mm)
方向
渲染显示

32

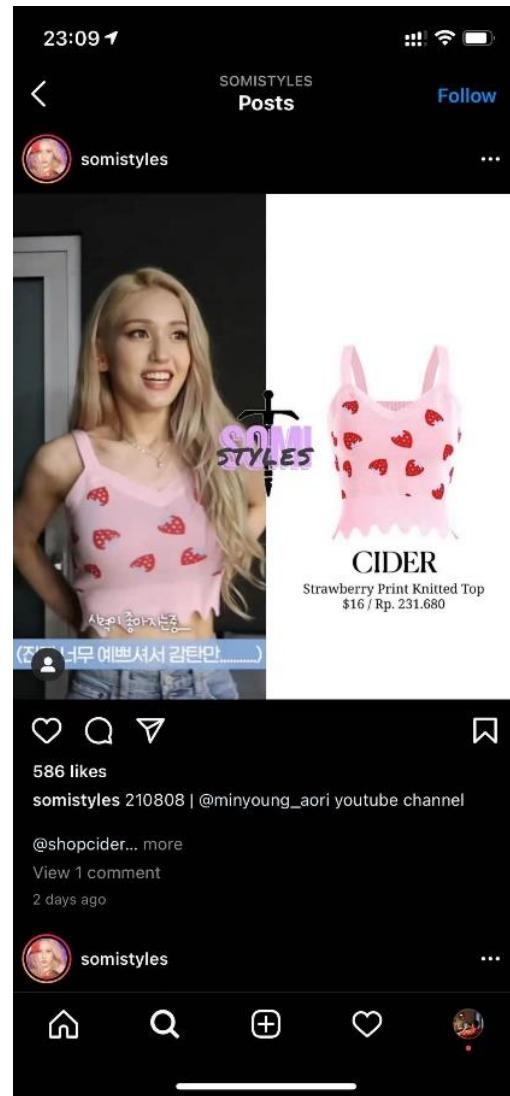
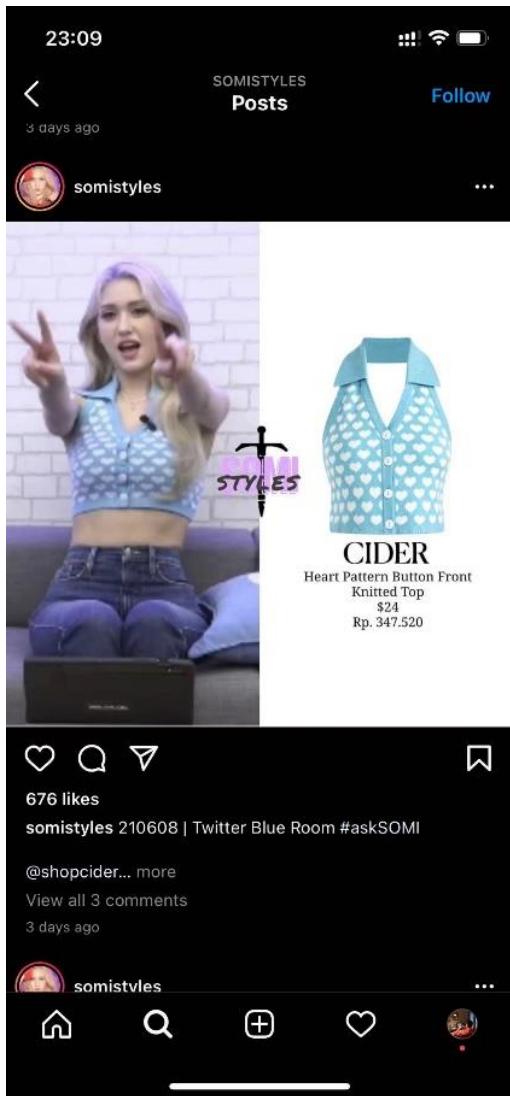
The screenshot displays the Style3D software interface, which is used for 3D garment design. The top bar includes standard application icons and tabs like '文件' (File), '开始' (Start), '版片' (Pattern), '素材' (Material), '测量' (Measure), '显示' (Display), and '设置' (Settings). A large title '冲锋衣三合一' (Three-in-one Windbreaker) is prominently displayed at the top right. The interface is divided into several main sections:

- Left Panel (工具栏):** Contains various tools and settings for material selection, pattern creation, and zipper placement.
- Middle Panel (2D版片视窗):** Shows the 2D pattern layout, featuring two front torso pieces and two side panels arranged on a grid.
- Right Panel (3D服装视窗):** Displays the final 3D model of a dark blue windbreaker jacket with orange accents and a black mesh panel on the chest.
- Properties Panel (右侧垂直栏):** Provides detailed settings for selected objects, including type, name, enable status, shadow, reflection, intensity, color, shape, width, height, direction, and rendering display.

Computer Graphics for Retail and Manufacturing



Computer Graphics for Retail and Manufacturing



Computer Graphics for VR, AR and Metaverse

Computer Graphics for Augmented Reality (AR)



Virtual Clothing



Photo



Virtual Clothing



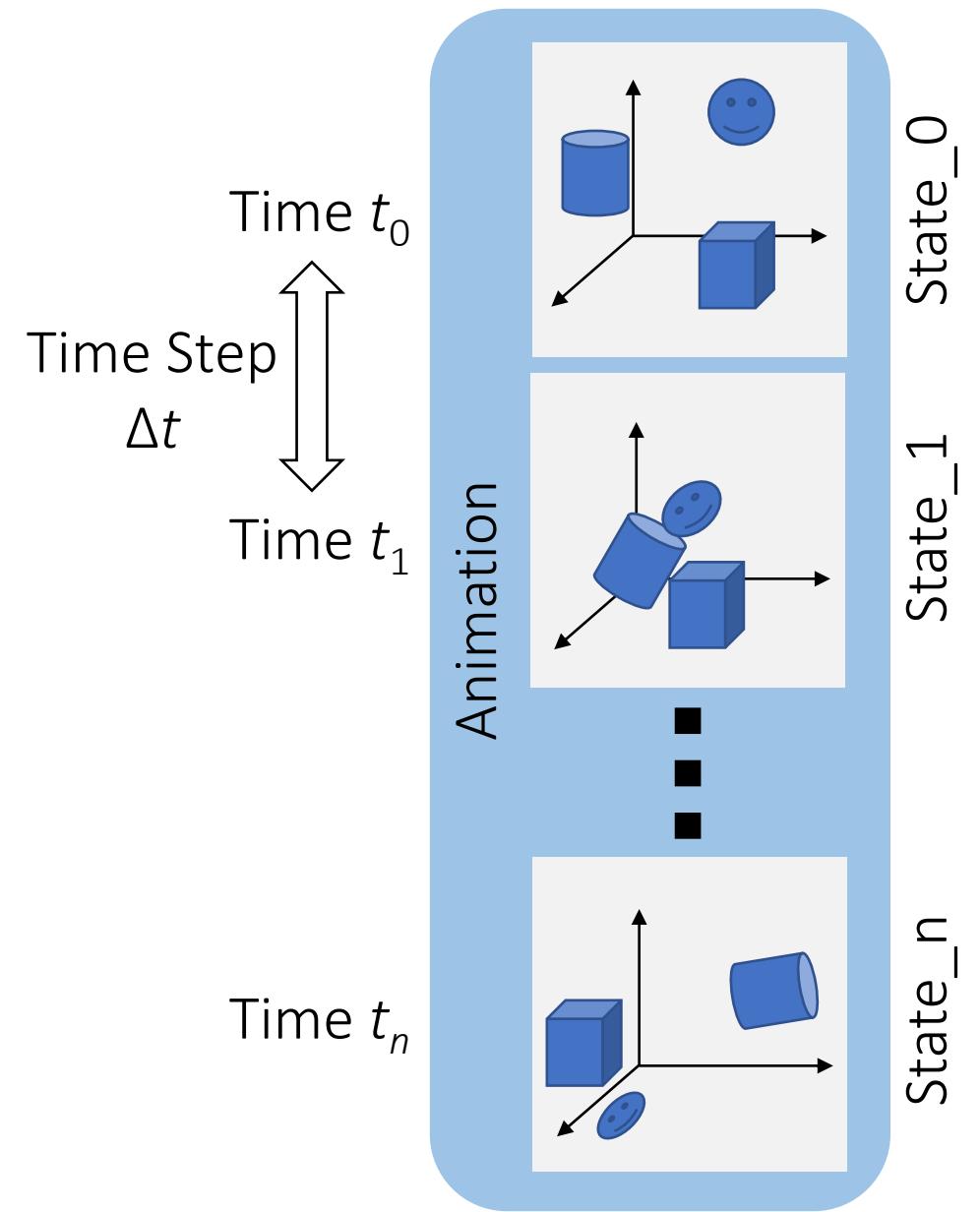
Photo

Issues for Discussion Today

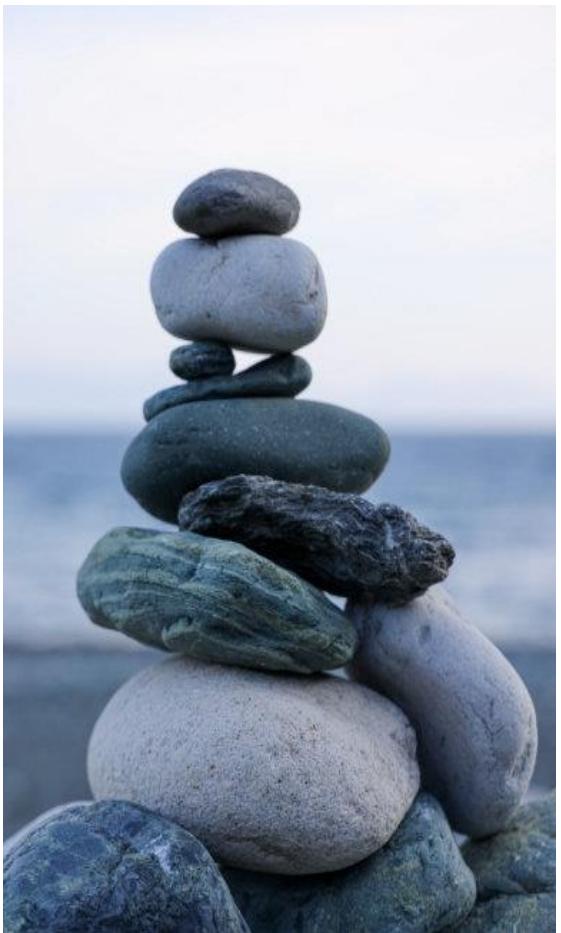
- What's computer graphics?
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Animation Paradigm

- The goal of animation is to update the state in every time step.
- The state can be:
 - Position/orientation
 - Velocity
 - Appearance
 - Density
 - ...
- The time step doesn't have to match the frame rate.
 - It's common to animate multiple time steps then render one frame.



Physics-Based Animation Topics



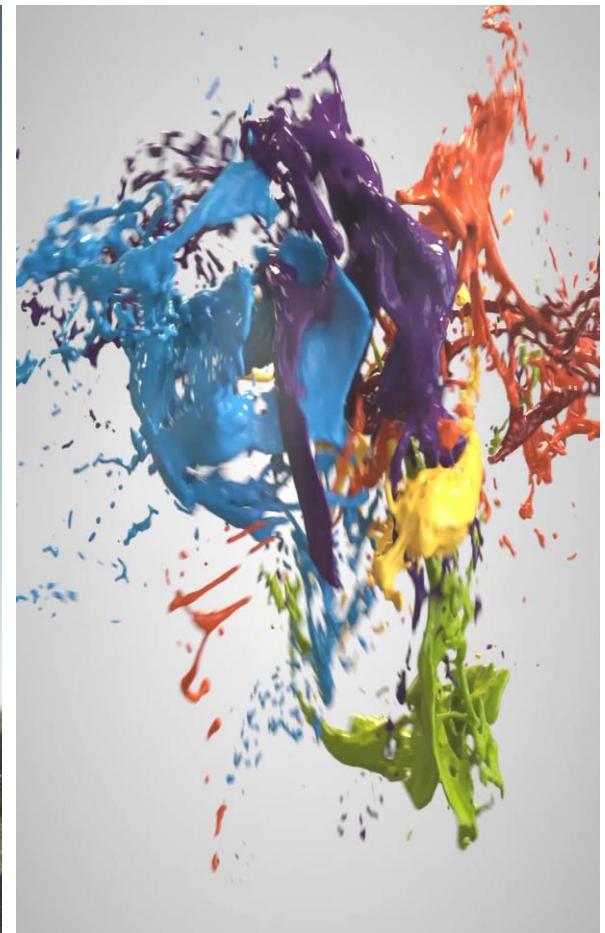
Rigid Bodies



Cloth and Hair



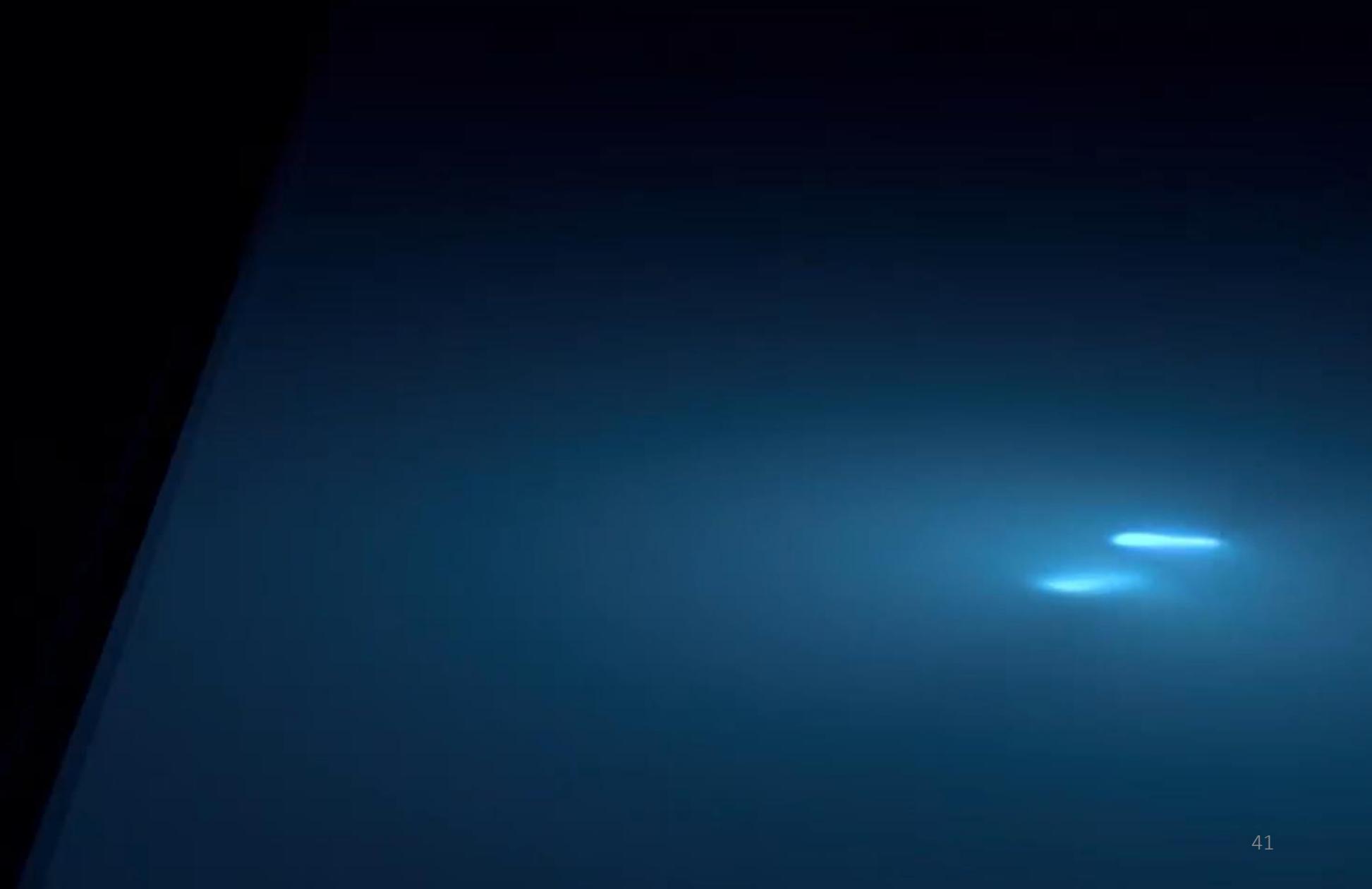
Soft Bodies

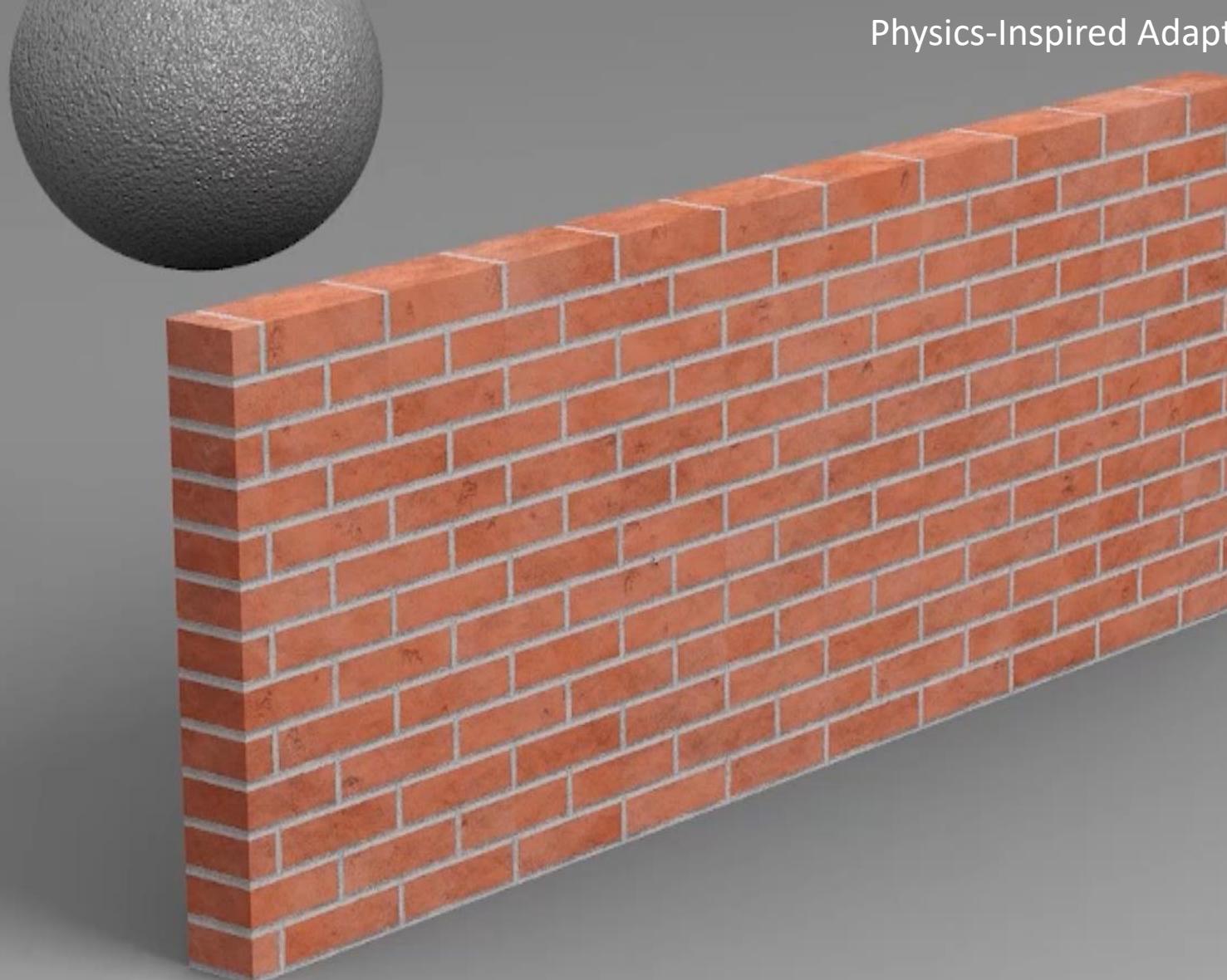


Fluids

Physics-Based Animation Topics

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies		Fluids	
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓			
Particle									
Grid									







Input

GPU-Based Simulation Result of Cloth Wrinkles at Submillimeter Levels (SIGGRAPH 2021)



Neo-Hookean



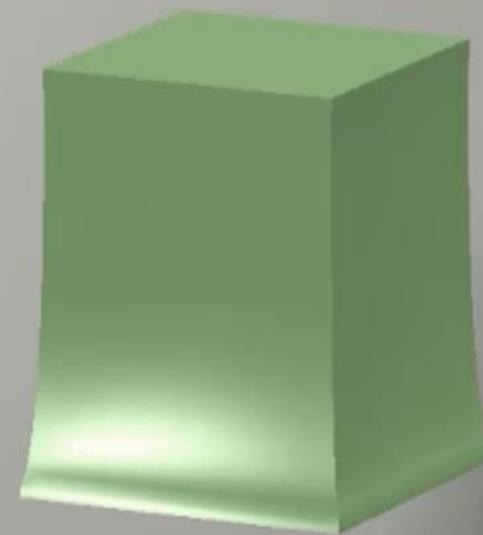
Mooney-Rivlin

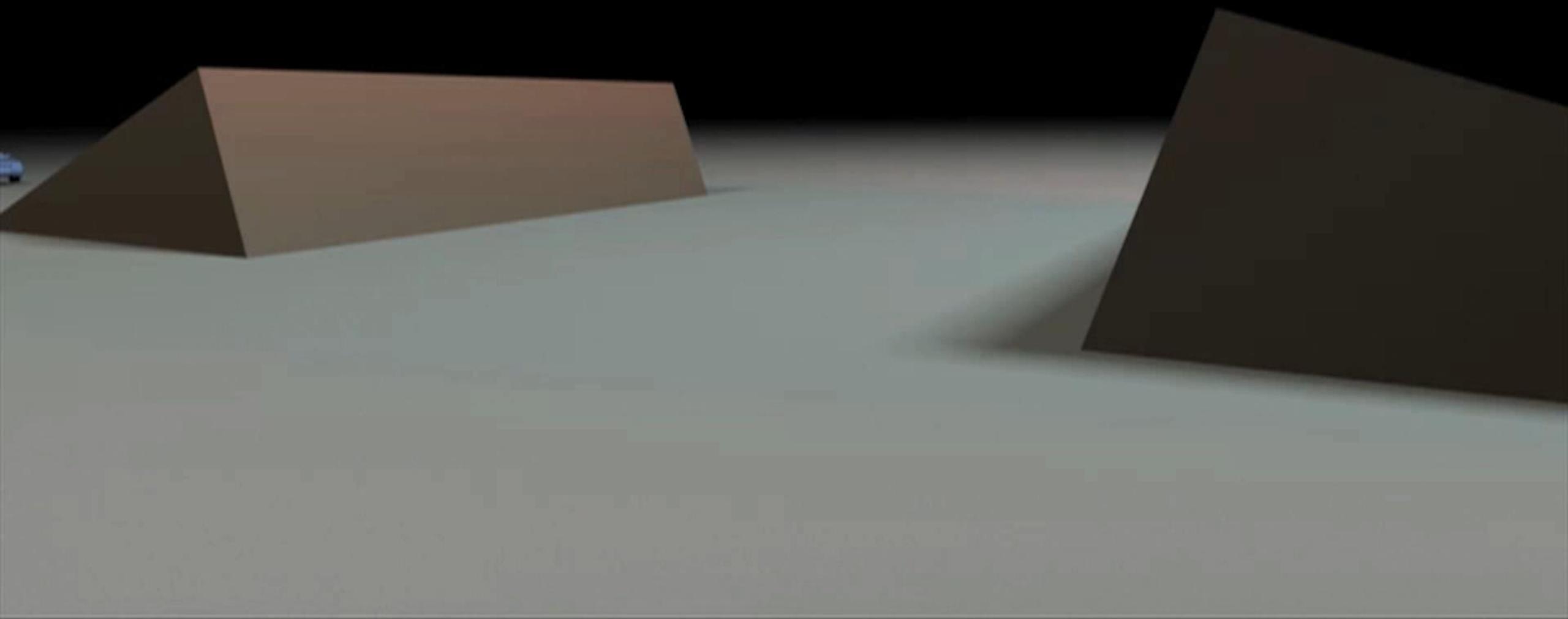


Fung



StVK





Physics-Based Animation Topics

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies		Fluids	
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓			
Particle		 (meshless)							
Grid			 (contact)  (contact)						

To avoid remeshing 

To simplify contacts 



Physics-Based Animation Topics

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies			Fluids
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓			
Particle		★ (meshless)					✓ (real-time)		
Grid			★ (contact)	★ (contact)			✓		





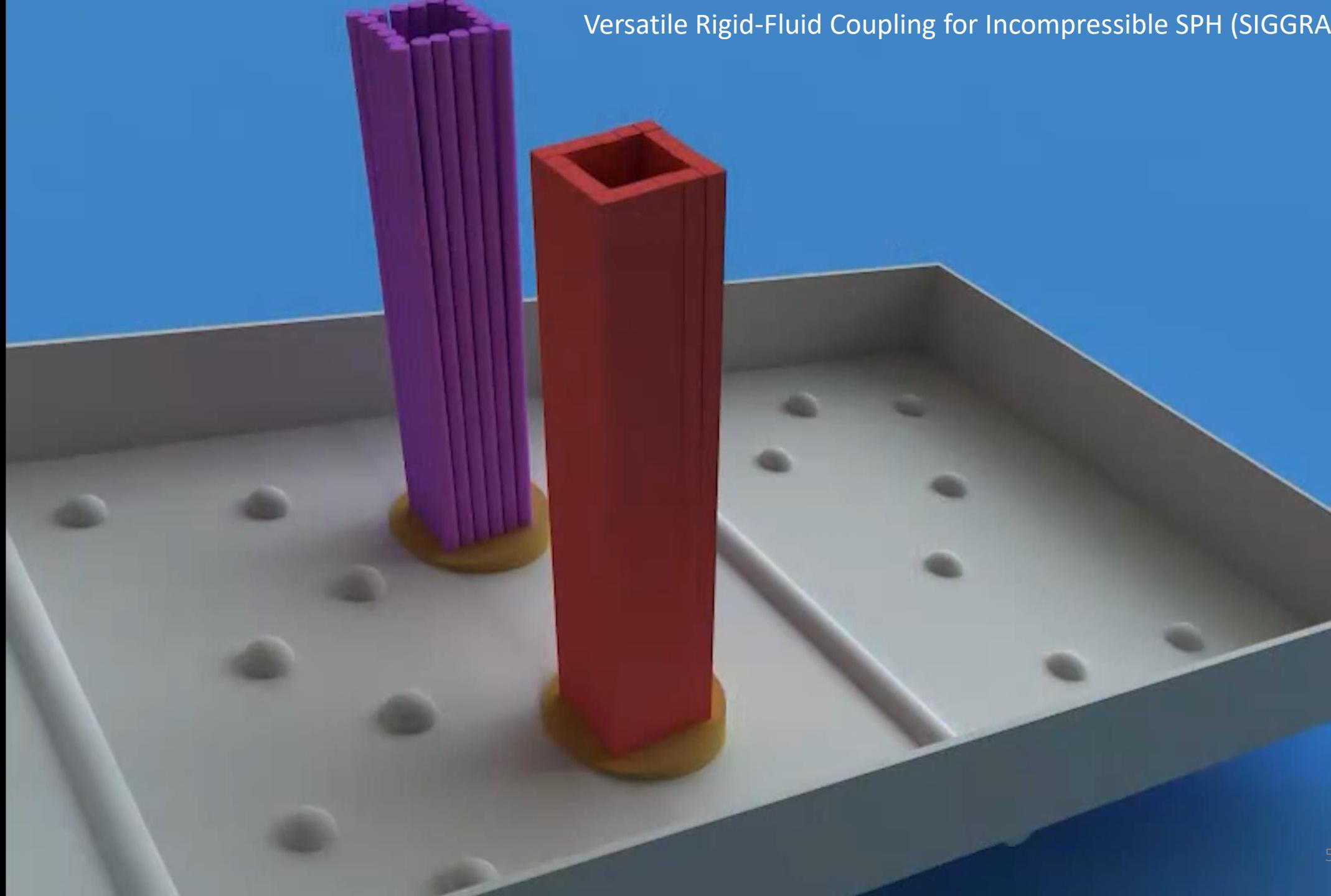
Physics-Based Animation Topics

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies			Fluids
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓		✓ (real-time)	
Particle		★ (meshless)					✓ (real-time)		
Grid			★ (contact)	★ (contact)			✓	✓	



Physics-Based Animation Topics

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies			Fluids
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓		✓ (real-time)	?
Particle		★ (meshless)					✓ (real-time)		✓
Grid			★ (contact)	★ (contact)			✓	✓	✓



Physics-Based Animation Topics

Coupling

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies		Fluids	
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh ↔	✓	✓	✓	✓	✓	✓		✓ (real-time)	?
Particle ↔		★ (meshless)					✓ (real-time)		✓
Grid ↔			★ (contact)	★ (contact)			✓	✓	✓

Hybrid Methods



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Topics in This Class

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies			Fluids
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓		✓ (real-time)	?
Particle		★ (meshless)					✓ (real-time)		✓
Grid			★ (contact)	★ (contact)			✓	✓	✓

My Own Expertise

Contents		Rigid Bodies		Cloth and Hair		Soft Bodies			Fluids
Effects	Contacts	Fracture	Cloth	Hair	Elastic	plastic	Smoke	Drops and Waves	Splashes
Mesh	✓	✓	✓	✓	✓	✓	?		?
Particle		★ (meshless)					✓ (real-time)		✓
Grid			★ (contact)	★ (contact)			✓	✓	✓

No Experience  Full Experience



Questions?