

# Computer Graphics 3

## Physically Based Graphics

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# Content of CG3

## Introduction to Physically Based Simulation

- ◆ Newtonian Physics
- ◆ Core Principles of Physics

## Physically based rendering

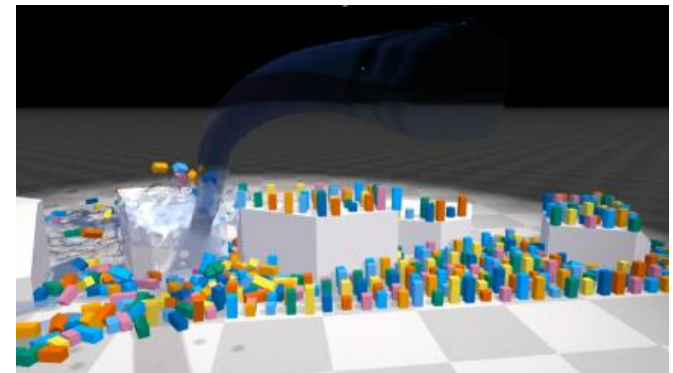
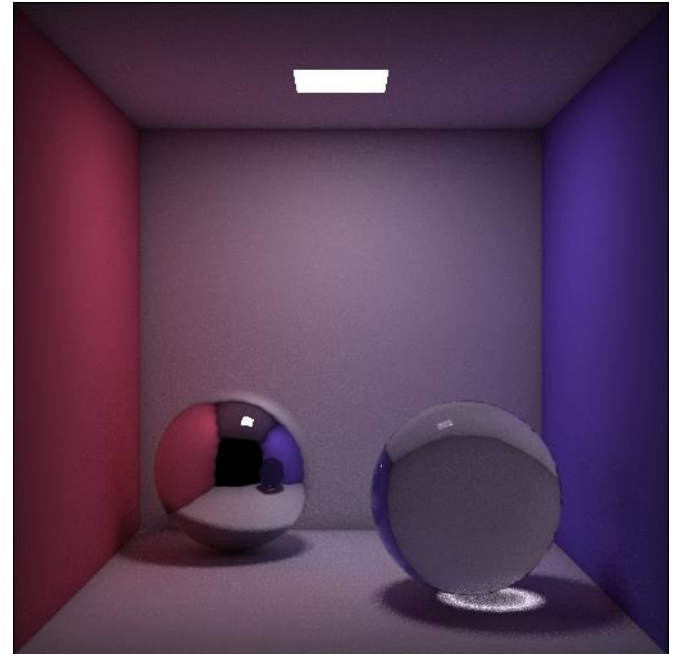
- ◆ Rendering equation
- ◆ Stochastic rendering
- ◆ Realistic materials
- ◆ Cache Based Methods

## Physically based simulation

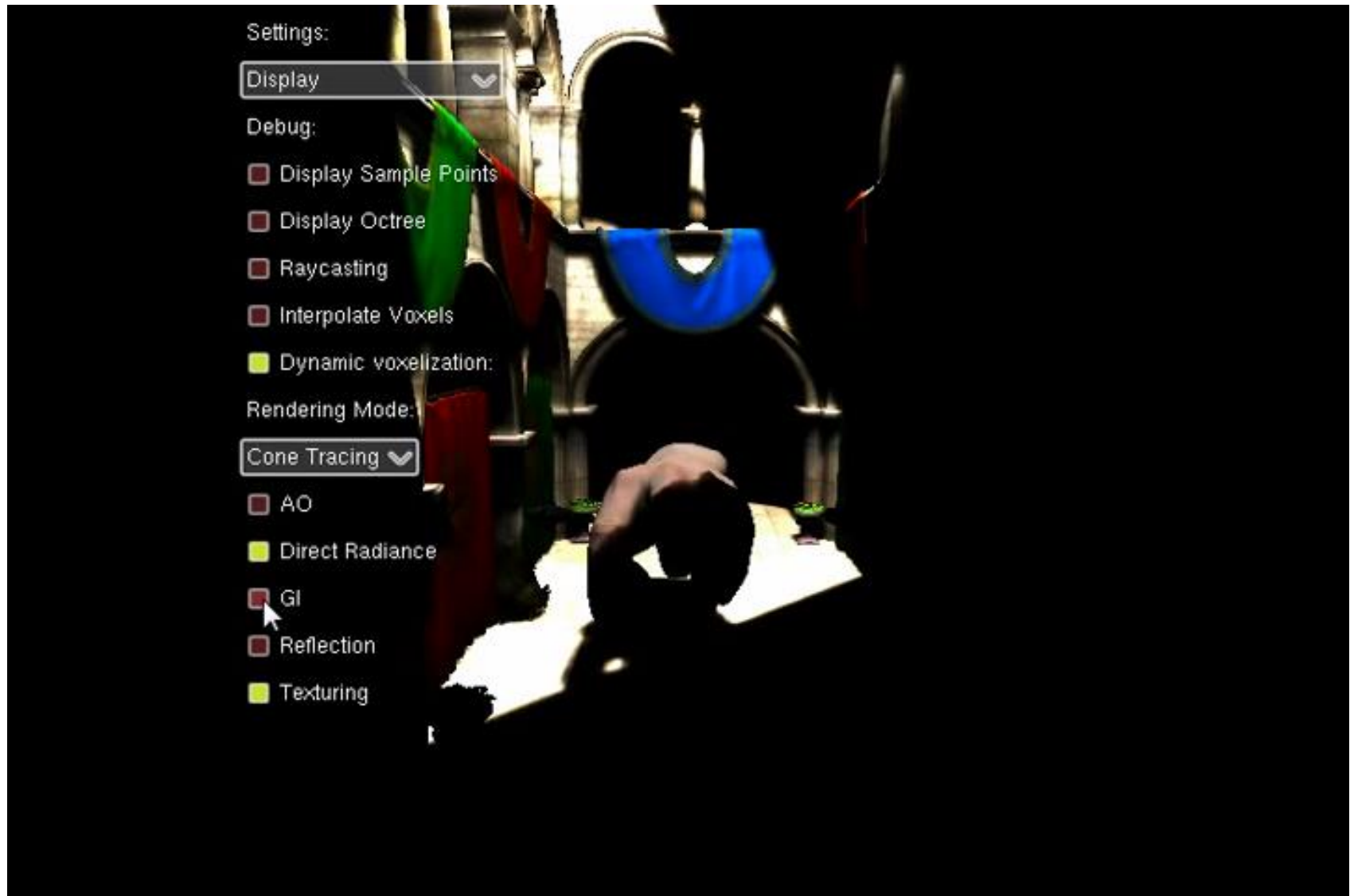
- ◆ Solving Ordinary Differential Equations
- ◆ Particle Based Simulation
- ◆ Rigid bodies
- ◆ Contact Handling
- ◆ Fluids

[Unified Particle  
Physics for  
Real-Time  
Applications](#)

Miles Macklin, Matthias  
Müller, Nuttapong  
Chentanez, Tae-Yong Kim



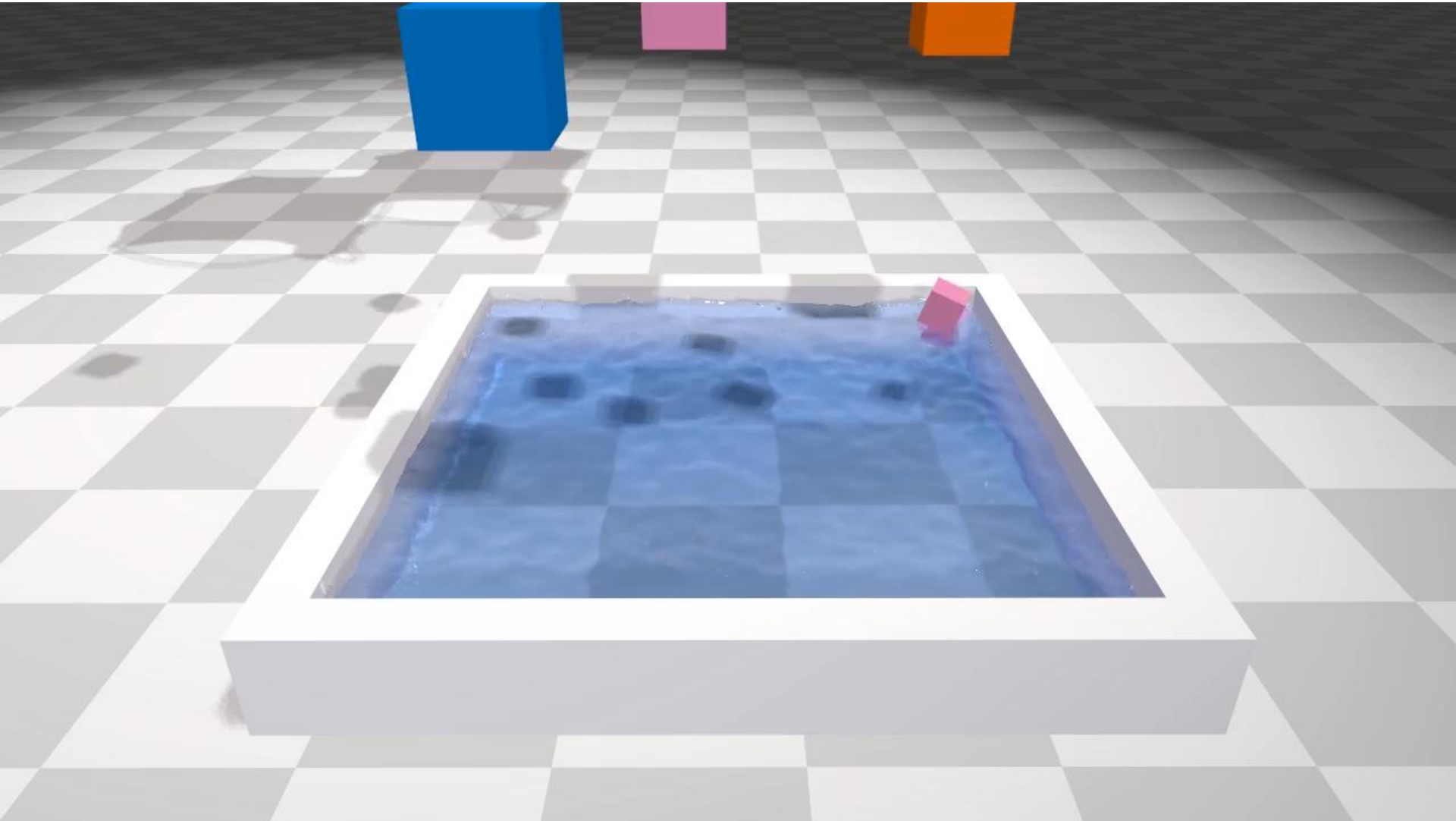
# Interactive Indirect Illumination Using Voxel Cone Tracing



# Unified Particle Physics for Real-Time Applications



Computergraphik  
und Visualisierung

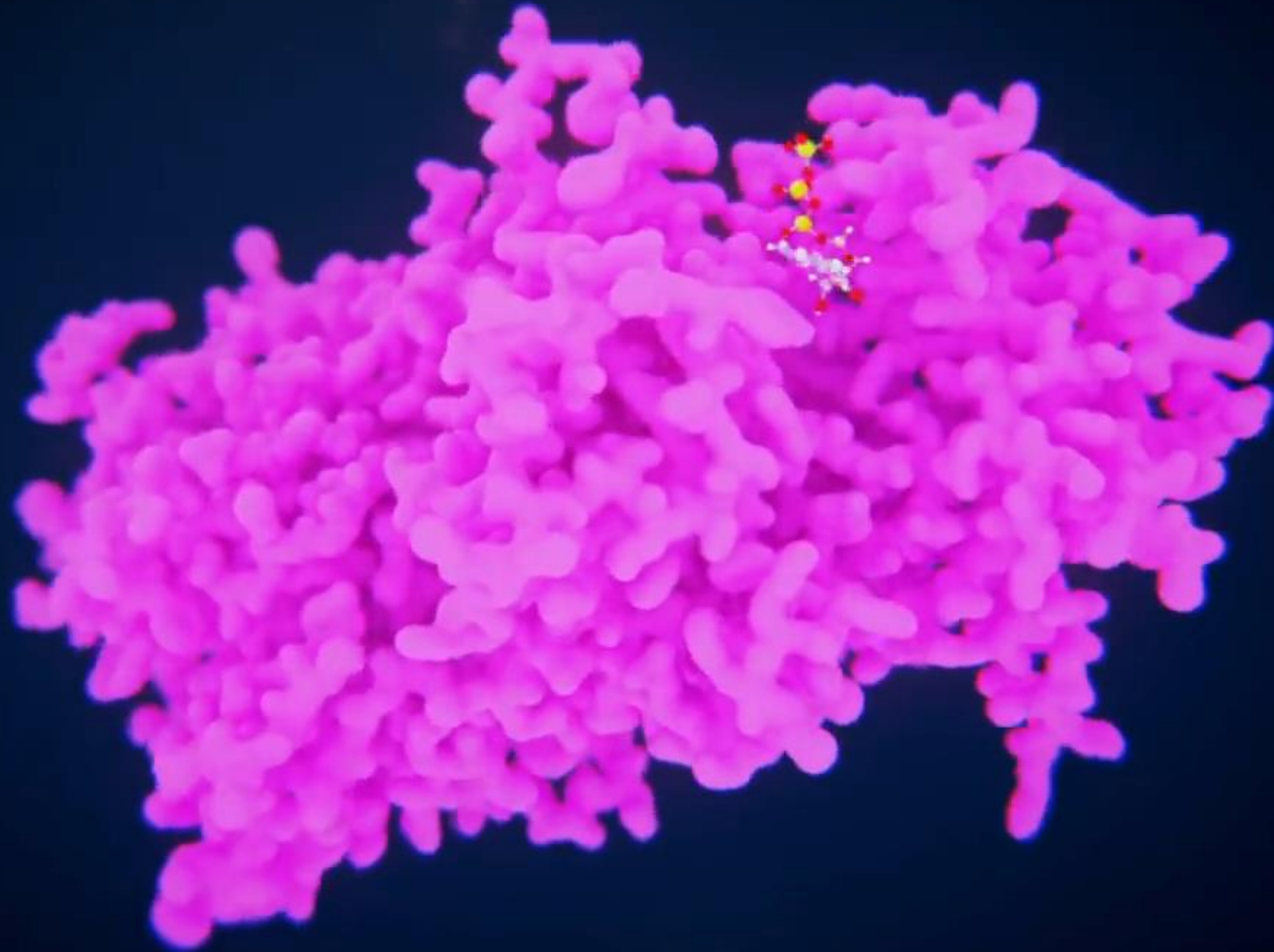


# Physically Based Simulation

## Molecular Simulation



Computergraphik  
und Visualisierung





## MULTIPHASE: EXAMPLE



Without buoyancy interaction term



With buoyancy interaction term





## A Multi-Scale Model for Simulating Liquid-Hair Interactions

SIGGRAPH 2017

**Video Contains Voice Over**

Yun (Raymond) Fei Henrique Teles Maia Christopher Batty Changxi Zheng Eitan Grinspun  
Columbia University and University of Waterloo



Clustering



## Quasi-Newton Methods for Real-time Simulation of Hyperelastic Materials

**Tiantian Liu**

University of Pennsylvania

**Sofien Bouaziz**

EPFL

**Ladislav Kavan**

University of Utah

**(contains narration)**



## I. Karate

Avg. sim time/frame: 33.02s  
Speed-up: 2.39×

# Physically Based Simulation

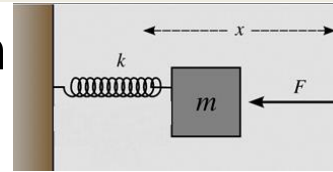
## Application Areas



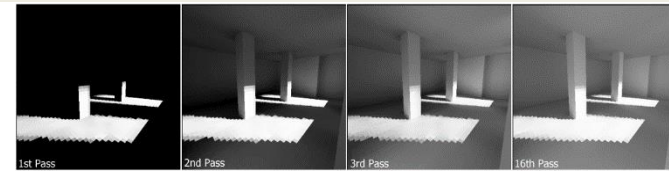
- ◆ Discrete Element Method
  - ◆ [molecular dynamics](#),
  - ◆ [sand](#), soil
- ◆ CFD (grid based or SPH)
  - ◆ [shallow water](#), [fluids](#),
  - ◆ gases, wind,
  - ◆ [smoke](#), [fire](#)
- ◆ Electro Dynamics
  - ◆ [magnets](#) and charges
- ◆ Radiometry
  - ◆ global illumination,
  - ◆ mobil radio coverage
- ◆ Elasticity (FD, FEM, Springs)
  - ◆ 1D: [hair](#), [wet hair](#)
  - ◆ 2D: [cloth](#)
  - ◆ 3D: [soft bodies](#), jelly, fat, muscles
- ◆ Stochastic Processes
  - ◆ [plant growth](#)
  - ◆ [weathering](#)
  - ◆ [lightning](#)
  - ◆ [crack formation](#), explosions

# Course Content

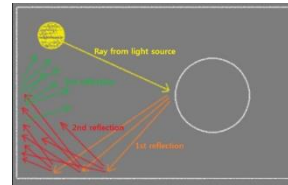
- physically based simulation
- Rendering Equation
- Monte Carlo integration
- sampling techniques
- path based rendering
- advanced materials
- cache based gi
- solving differential equations
- particle systems
- rigid bodies
- collisions
- fluids



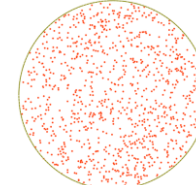
Harmonic Oscillator



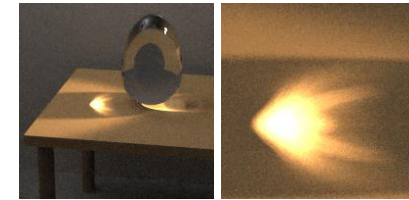
Iterative Solving Rendering Equation



Monte Carlo Integration



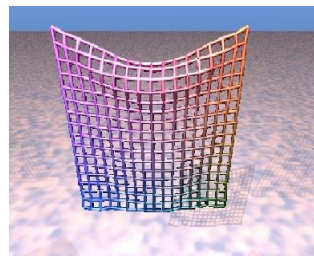
Sampling



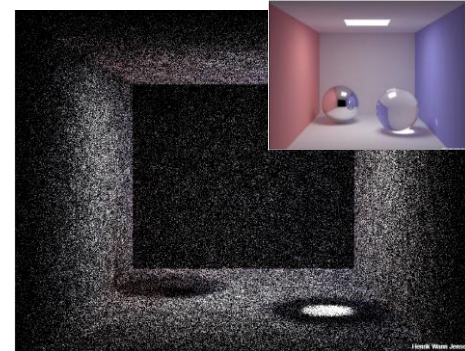
Path Based GI



Texture Material



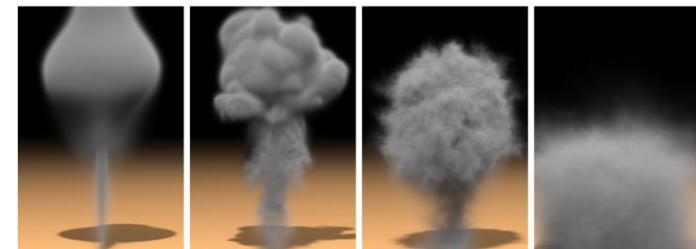
Simple Cloth Simulation



Photon Mapping



Colliding Rigid bodies



Vorticity Refinement