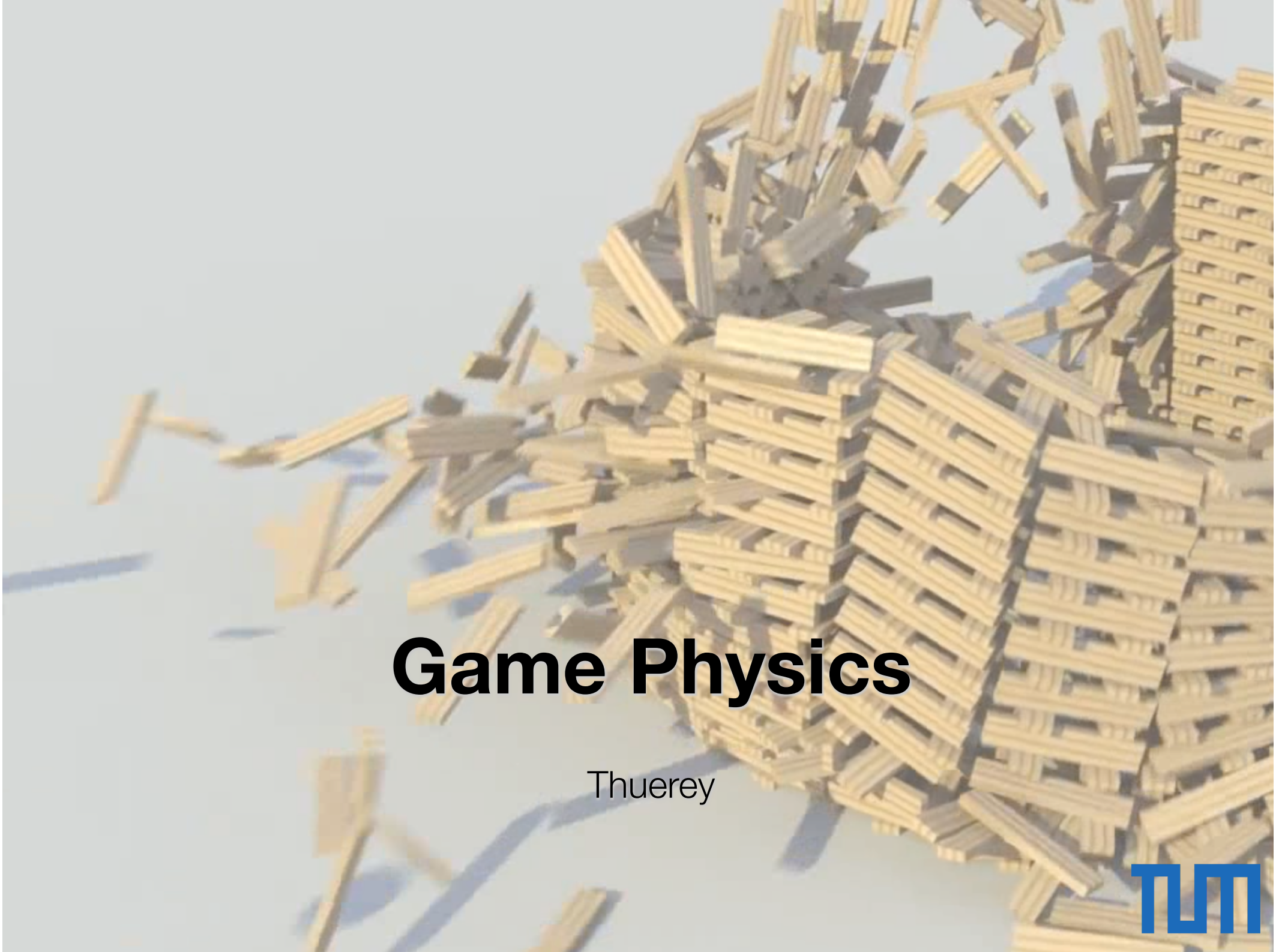
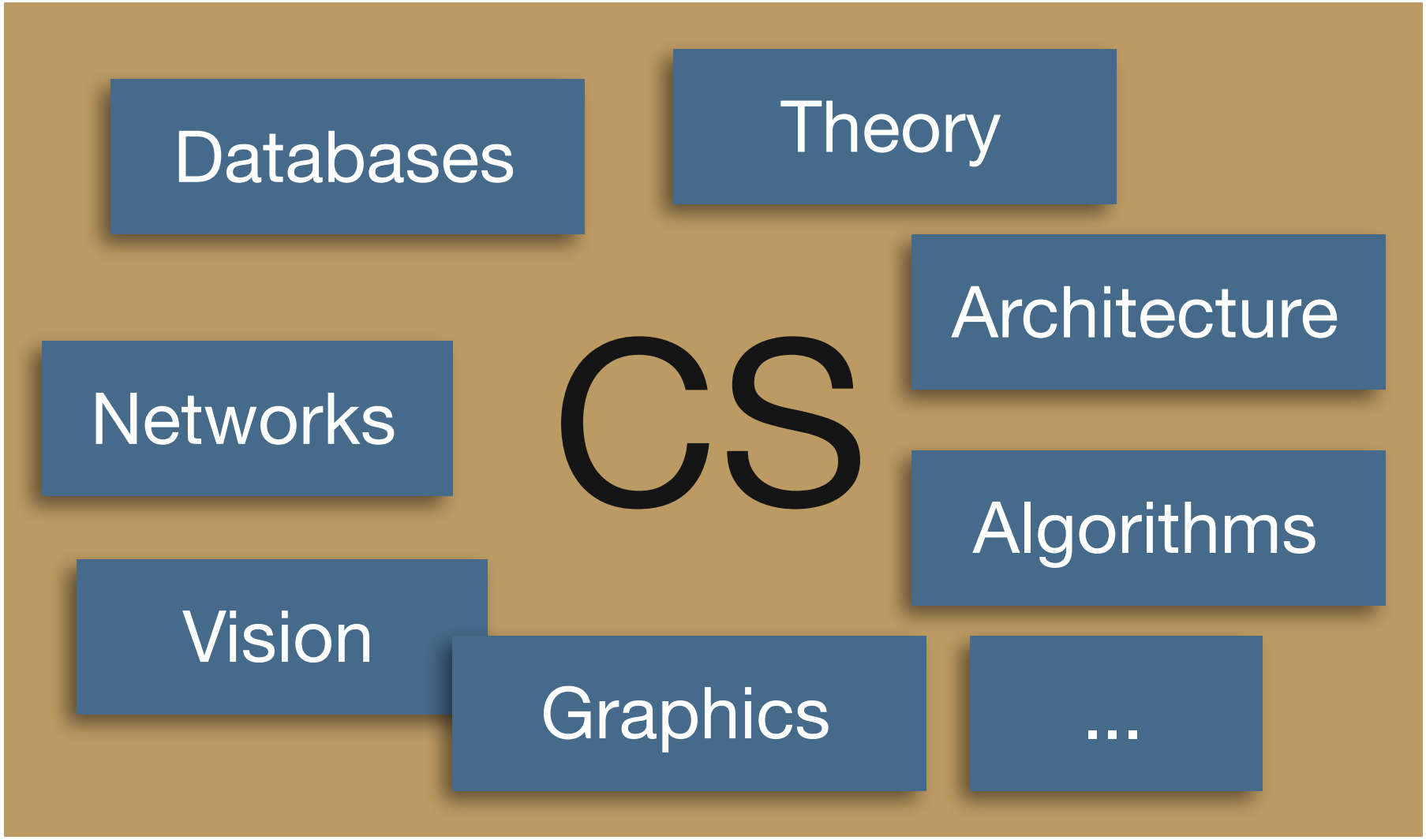


Game Physics

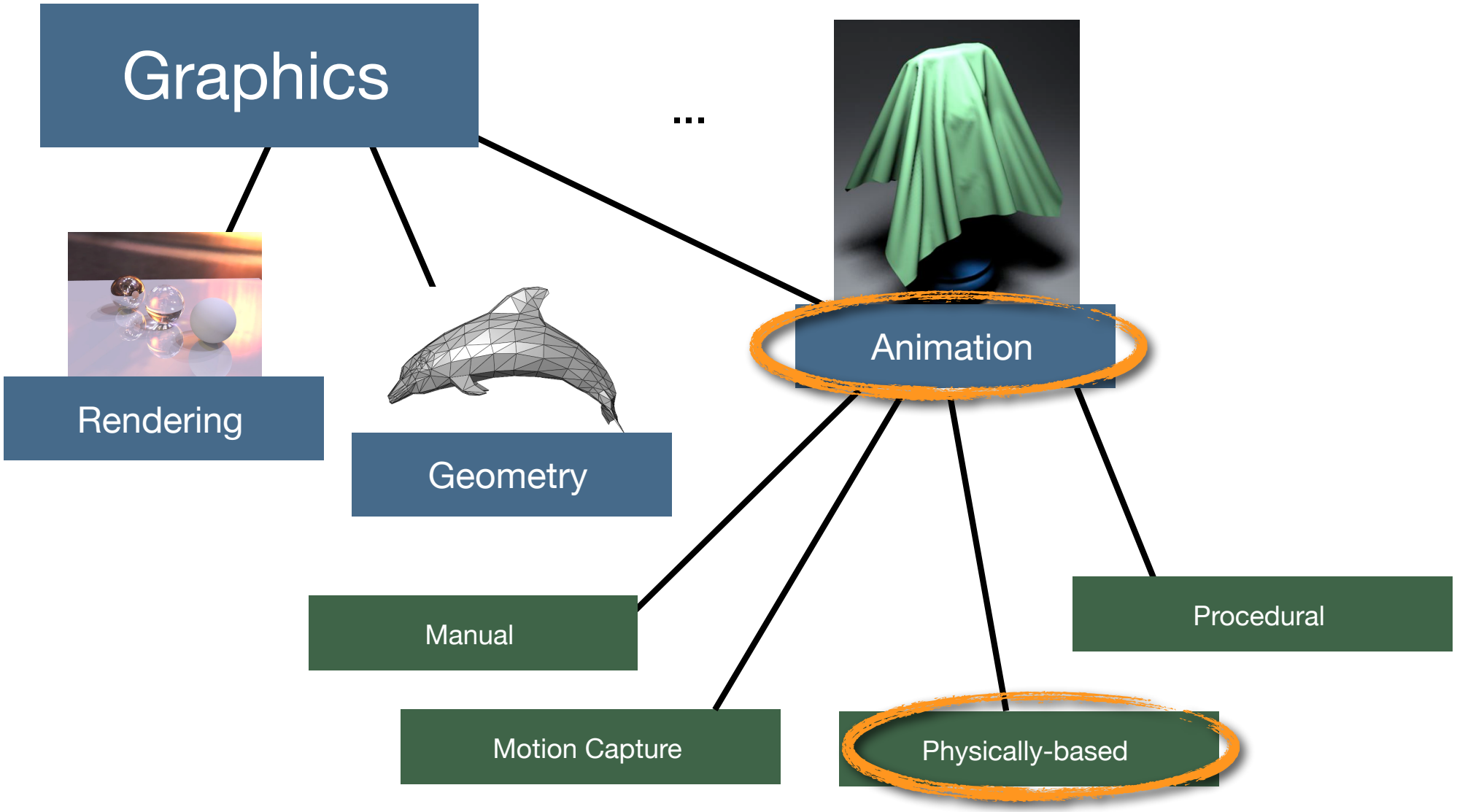
Thuerey

Background

Context


Databases
Theory
Architecture
Networks
CS
Algorithms
Vision
Graphics
...

Context


Graphics
...
Rendering
Geometry
Animation
Manual
Procedural
Motion Capture
Physically-based

Animate

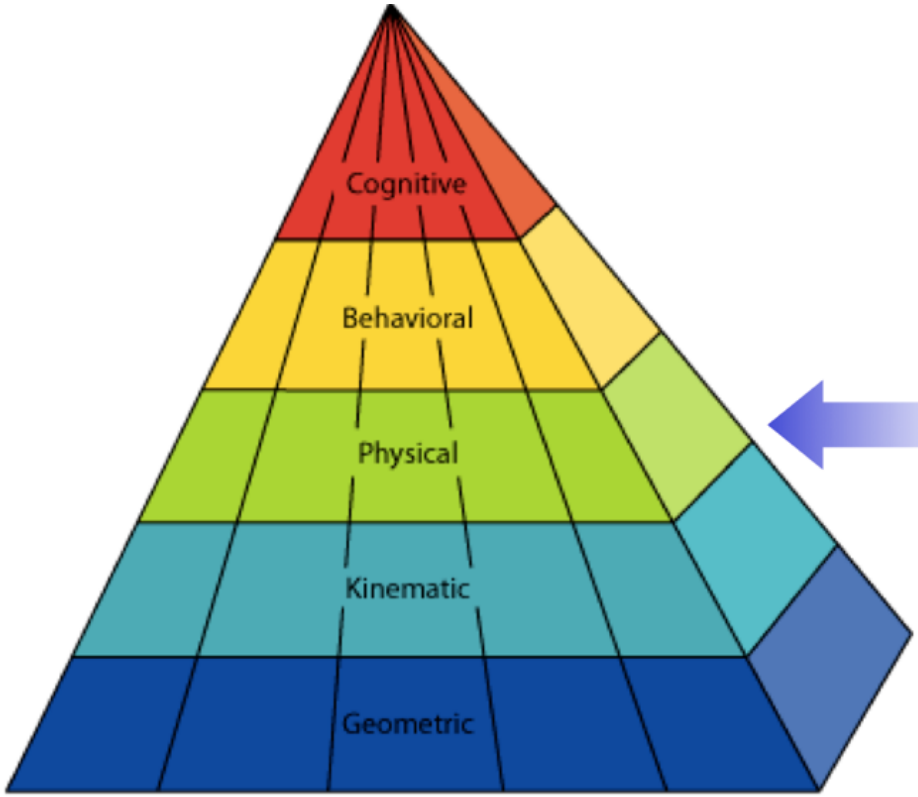
- From anima (lat.) = soul / spirit ,
  breath of life

- Examples
  - Characters: humans, animals
  - Secondary motion: hair, cloth
  - Materials: rigid bodies, water

Real-time Physics

- Interaction often *can't* be precomputed
  → Simulation
- Accuracy vs. speed
- Stability crucial
- Application areas:
  – Training
  – Education
  – Entertainment

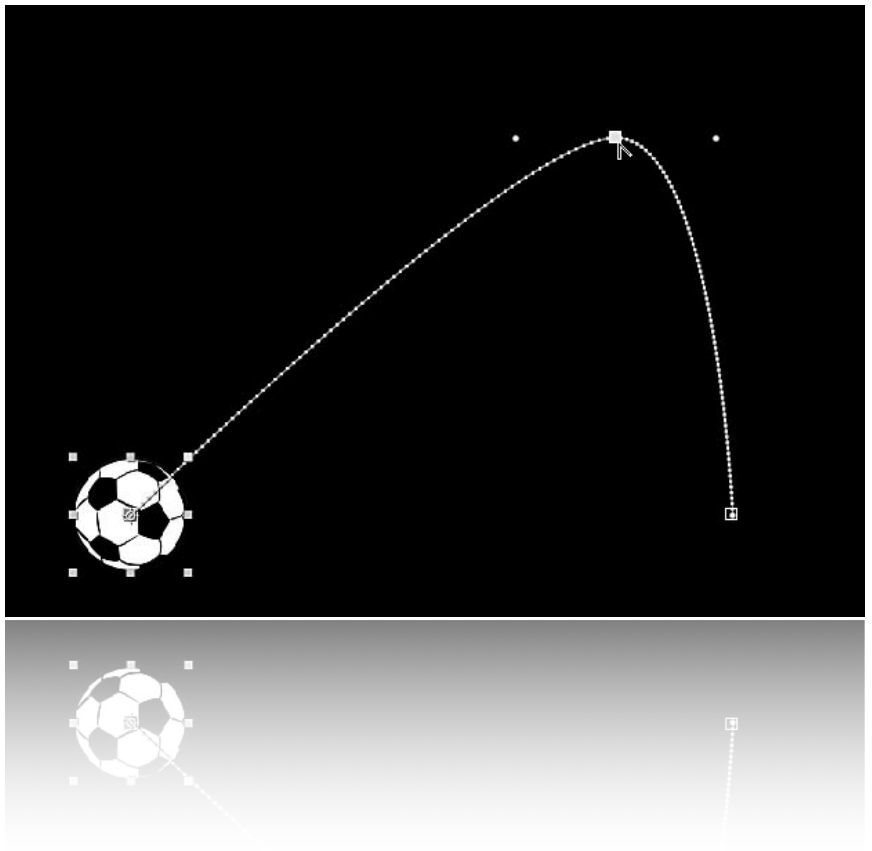
Modeling Pyramid in Games



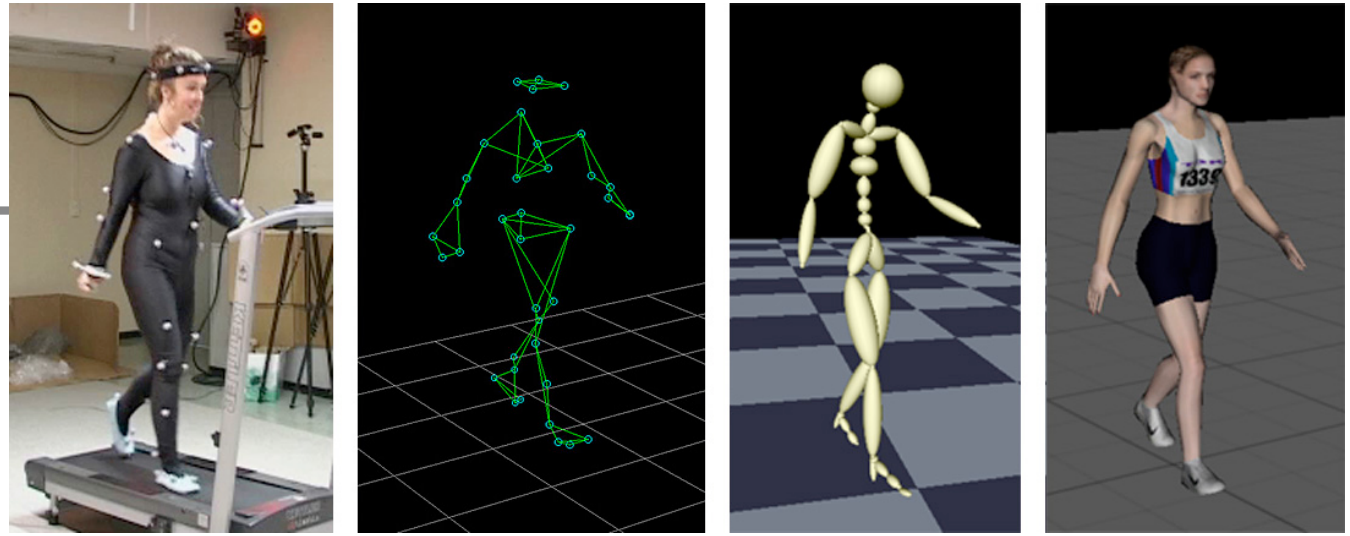
We're here!

Animation

- Conventional Animation
  - Place keyframes
  - Interpolate
  - Full control
  - Tedious
  - Non-interactive



Animation

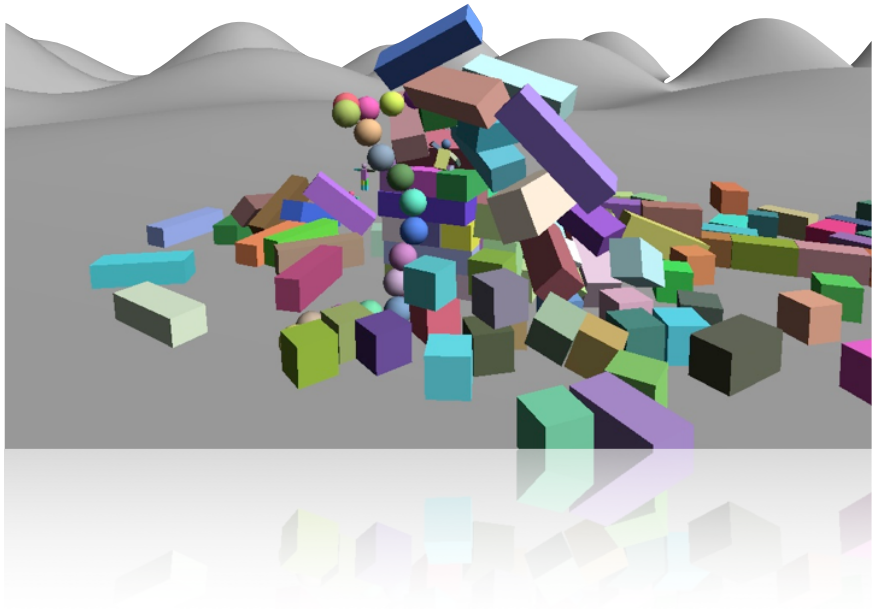


- Motion capture
  - Add markers, record motion, play back
  - Real performance
  - Loads of data...
  - Flying elephant?
  - “Not-really” interactive

Animation

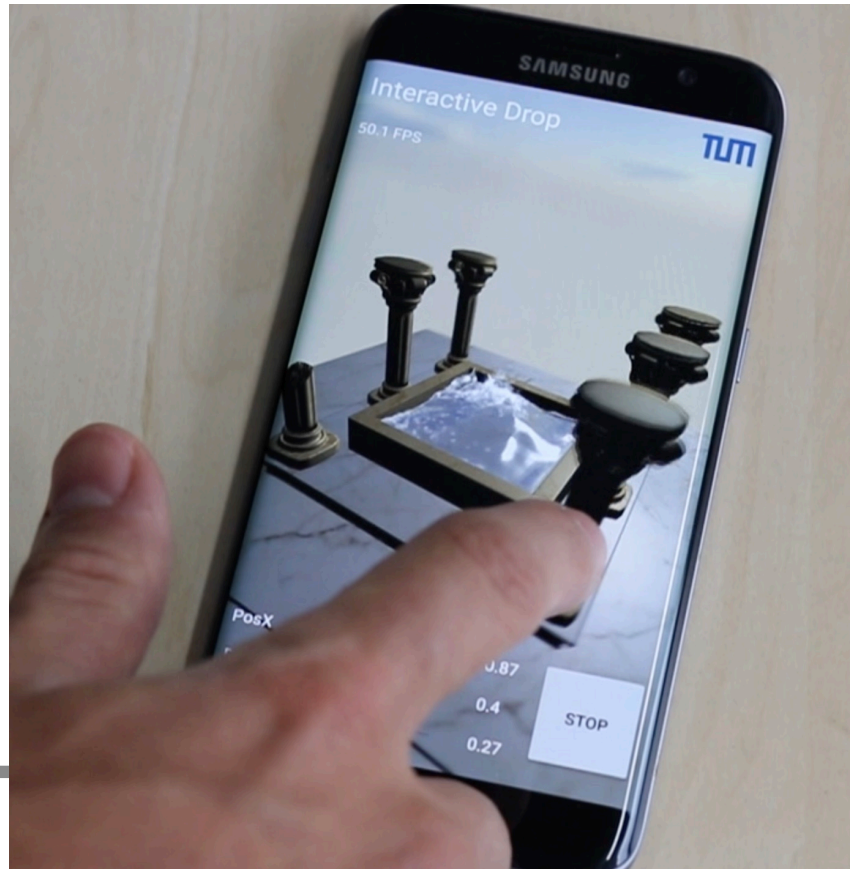
- Physically-based Animation
  - Driven by laws of physics
  - Can be computed in real-time

  - Fully interactive
  - But compute-intensive



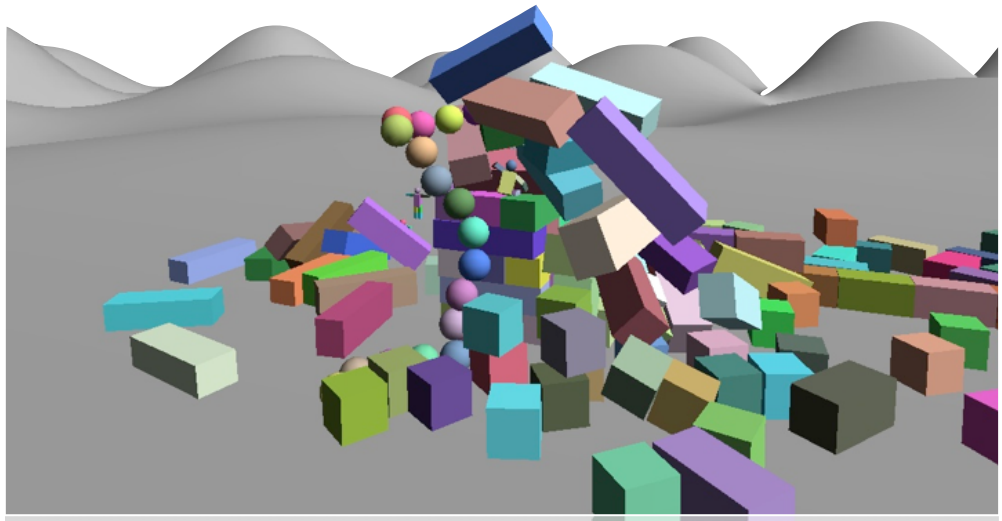
Animation

- Outlook
  - Combinations with machine learning
  - Neural networks as general function approximators

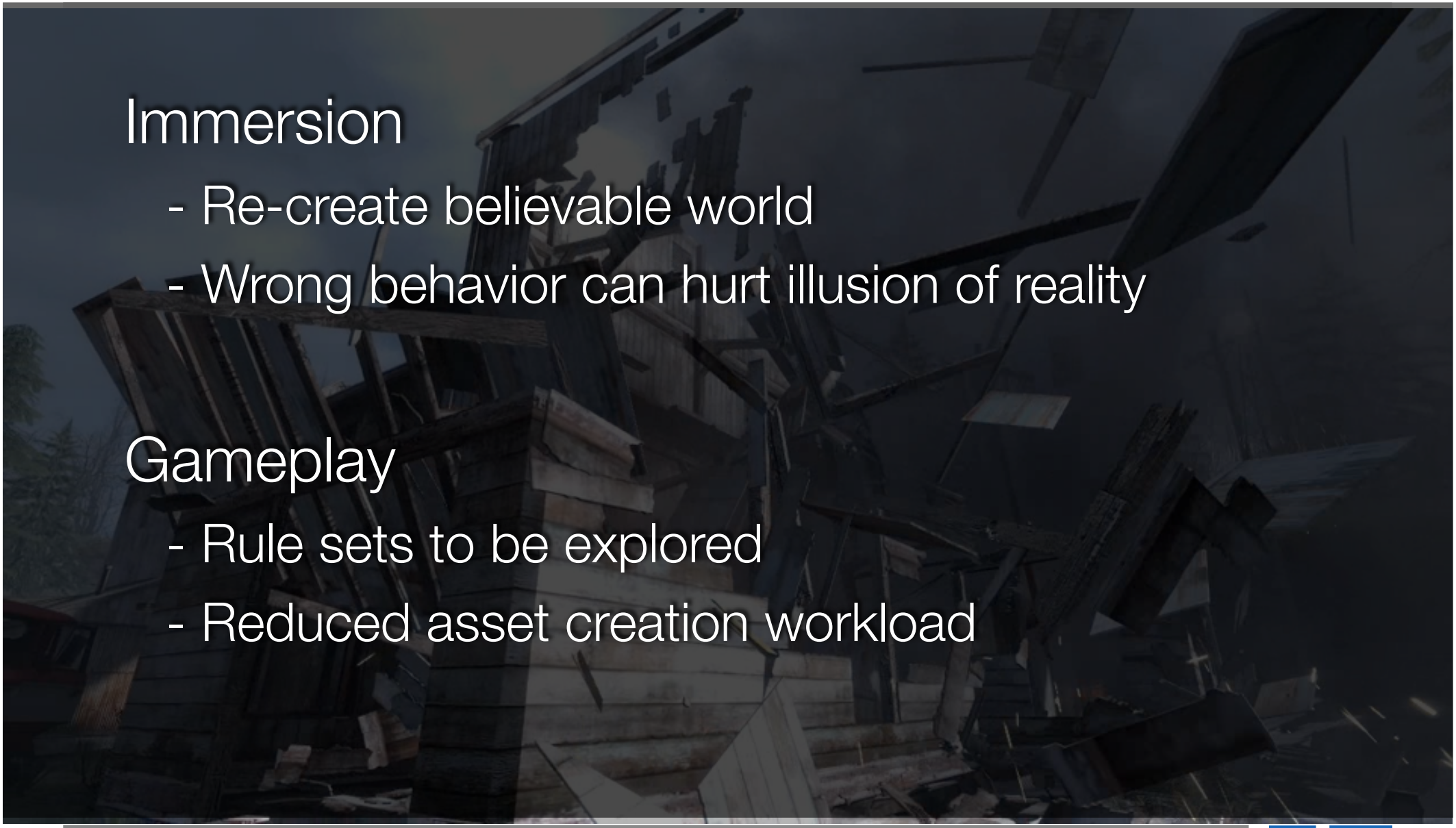


Animation

- Note on “Physics”
  - Meaning here: *mechanics*
  - Not: astronomy, electronics, geo-, laser-physics, optics, string theory...



Goals



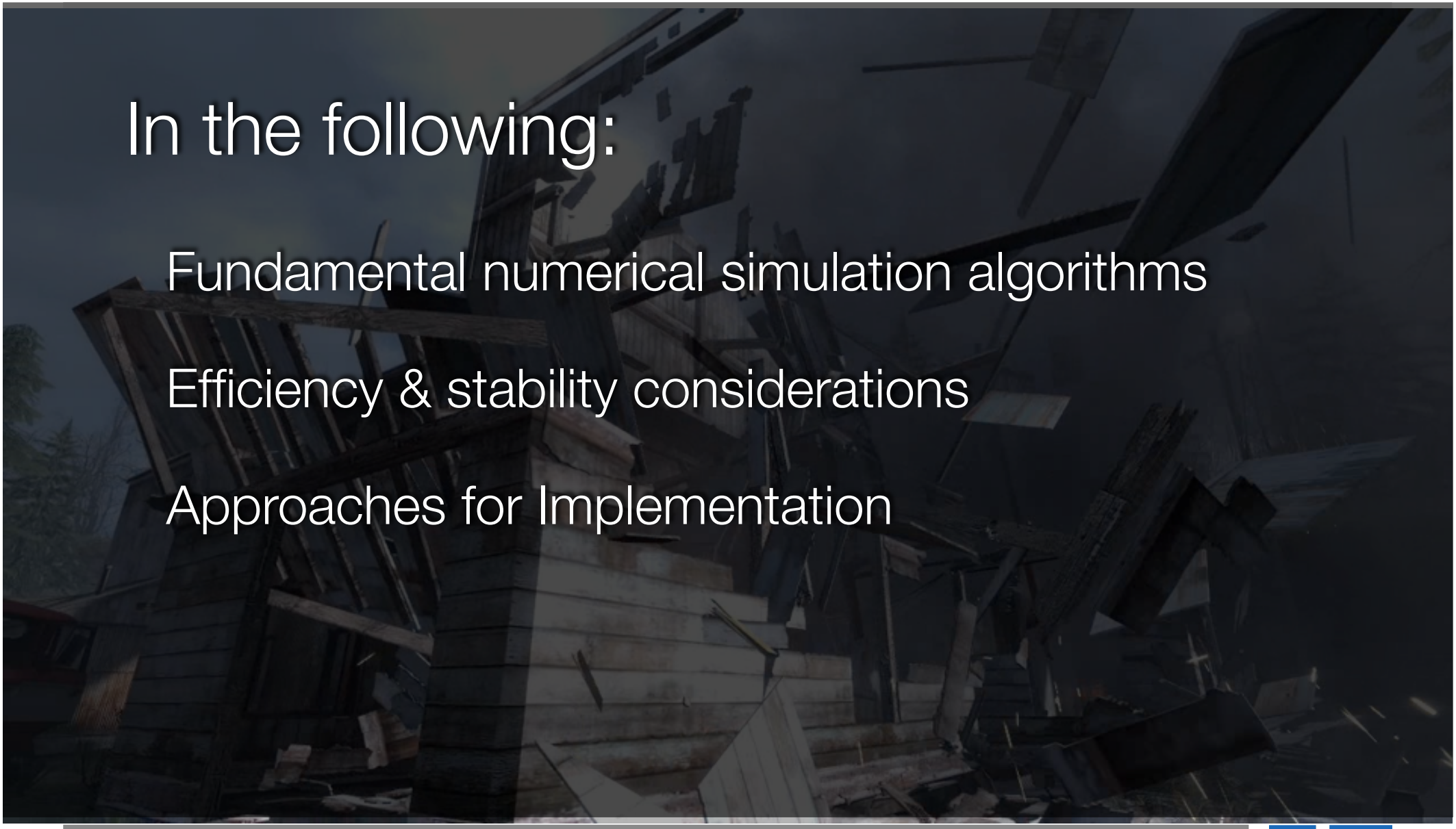
Immersion

- Re-create believable world
- Wrong behavior can hurt illusion of reality

Gameplay

- Rule sets to be explored
- Reduced asset creation workload

Goals



In the following:

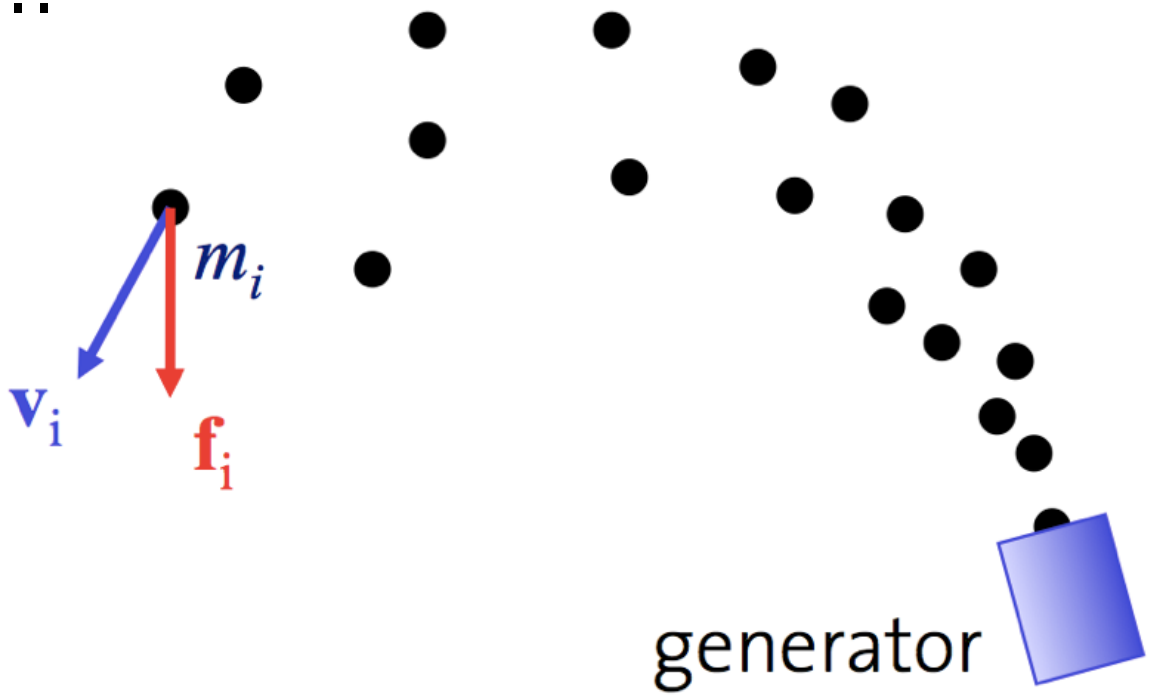
- Fundamental numerical simulation algorithms
- Efficiency & stability considerations
- Approaches for Implementation

Topics

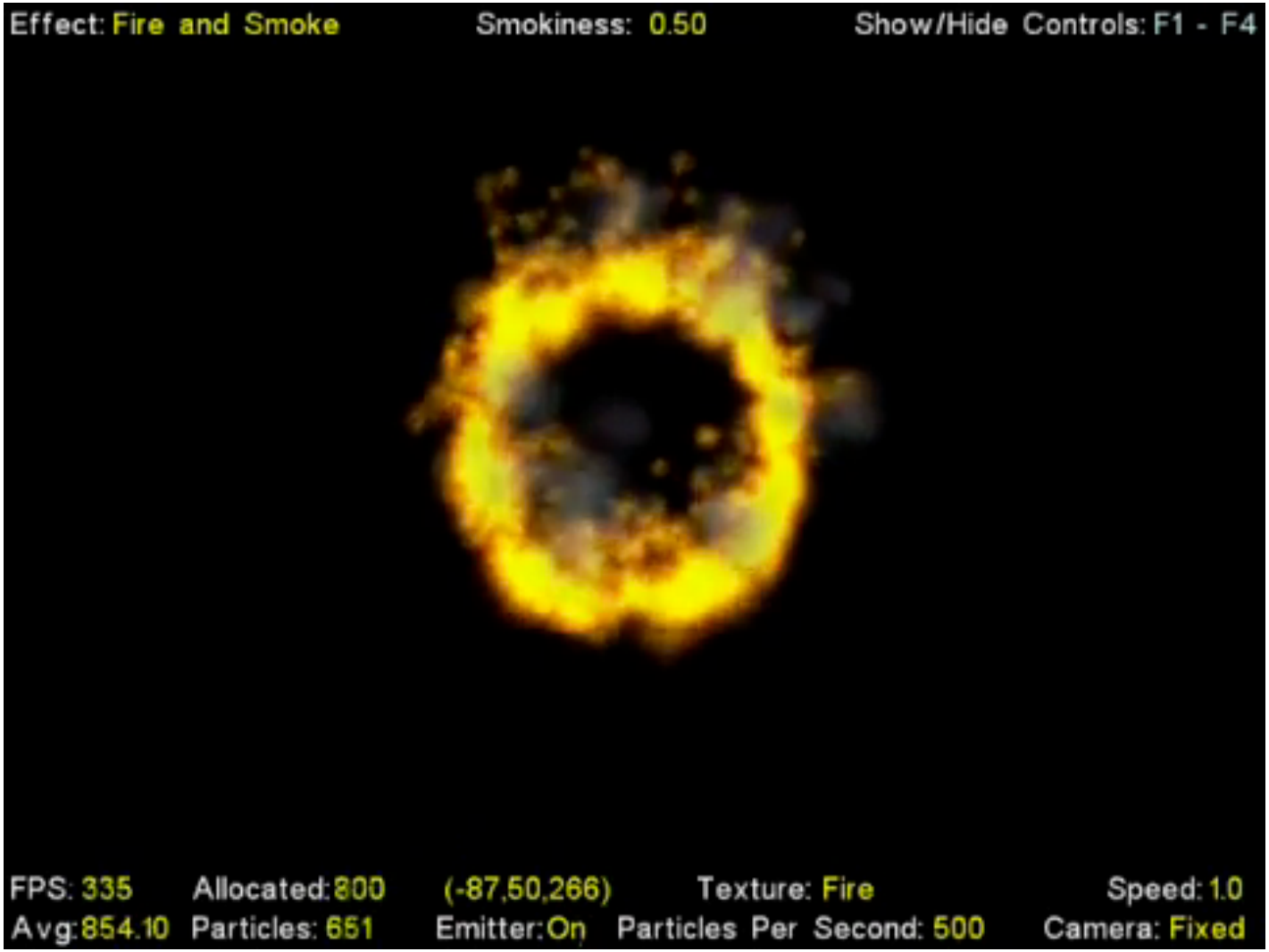
- Particles / integration methods
- Mass spring systems / deformables
- Rigid bodies
- Rigid body engines
- Fluid simulations

Particles

- As-simple-as possible primitives
- Motion influenced by forces
- Large numbers...

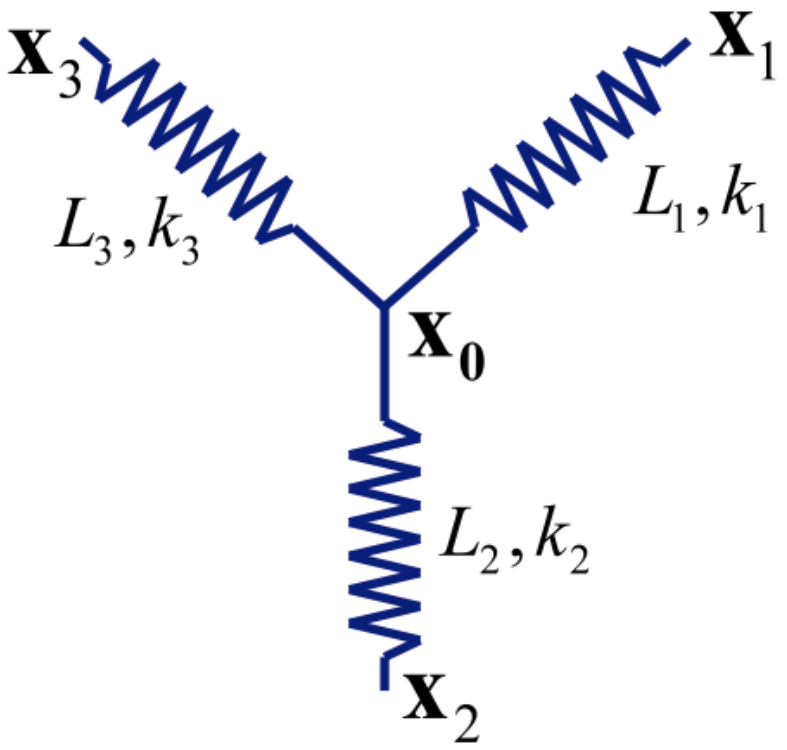


Particles

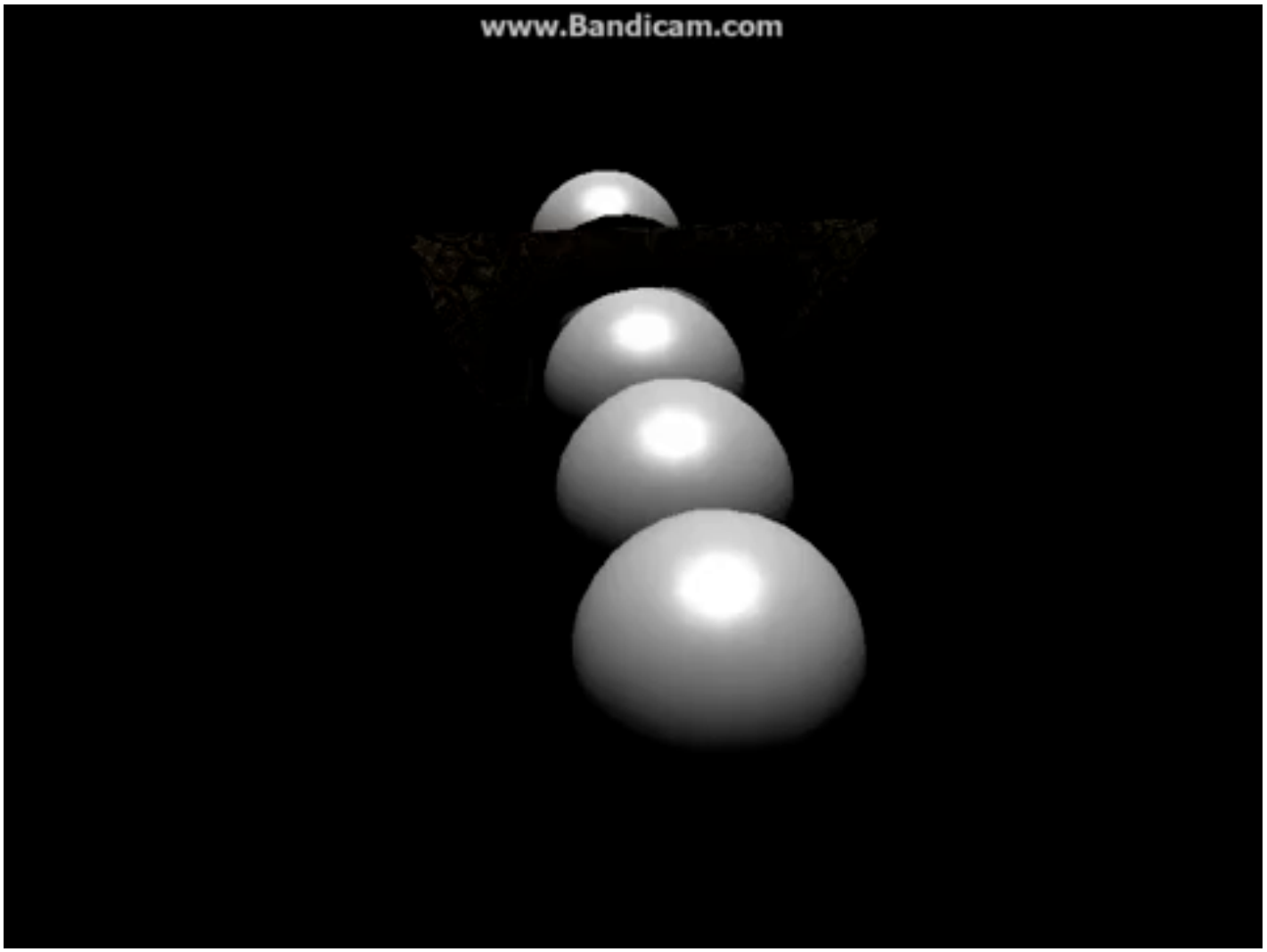

Effect: Fire and Smoke
Smokiness: 0.50
Show/Hide Controls: F1 - F4
FPS: 335
Allocated: 800
(-87,50,266)
Texture: Fire
Speed: 1.0
Avg: 854.10
Particles: 661
Emitter: On
Particles Per Second: 500
Camera: Fixed

Mass Spring Systems

- Particles + springs
- Interaction force
- Issues:
  - Placement
  - Collision
  - Stability

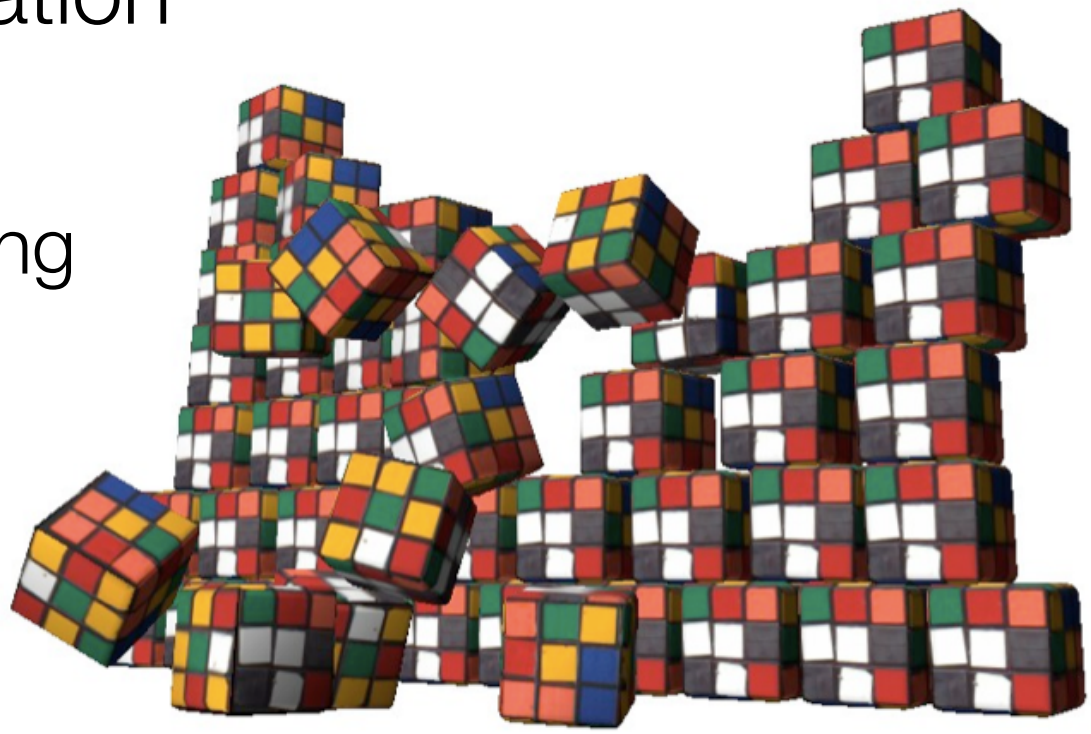


Mass Spring Systems

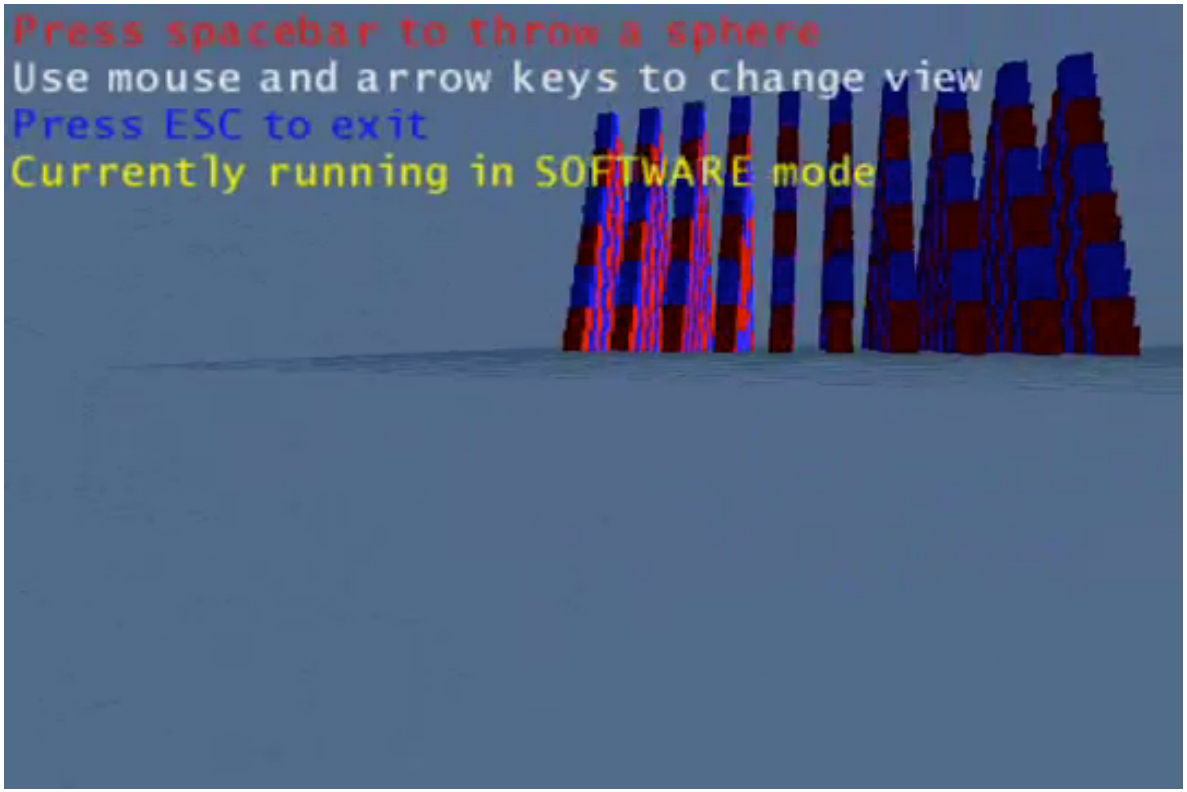


Rigid Bodies

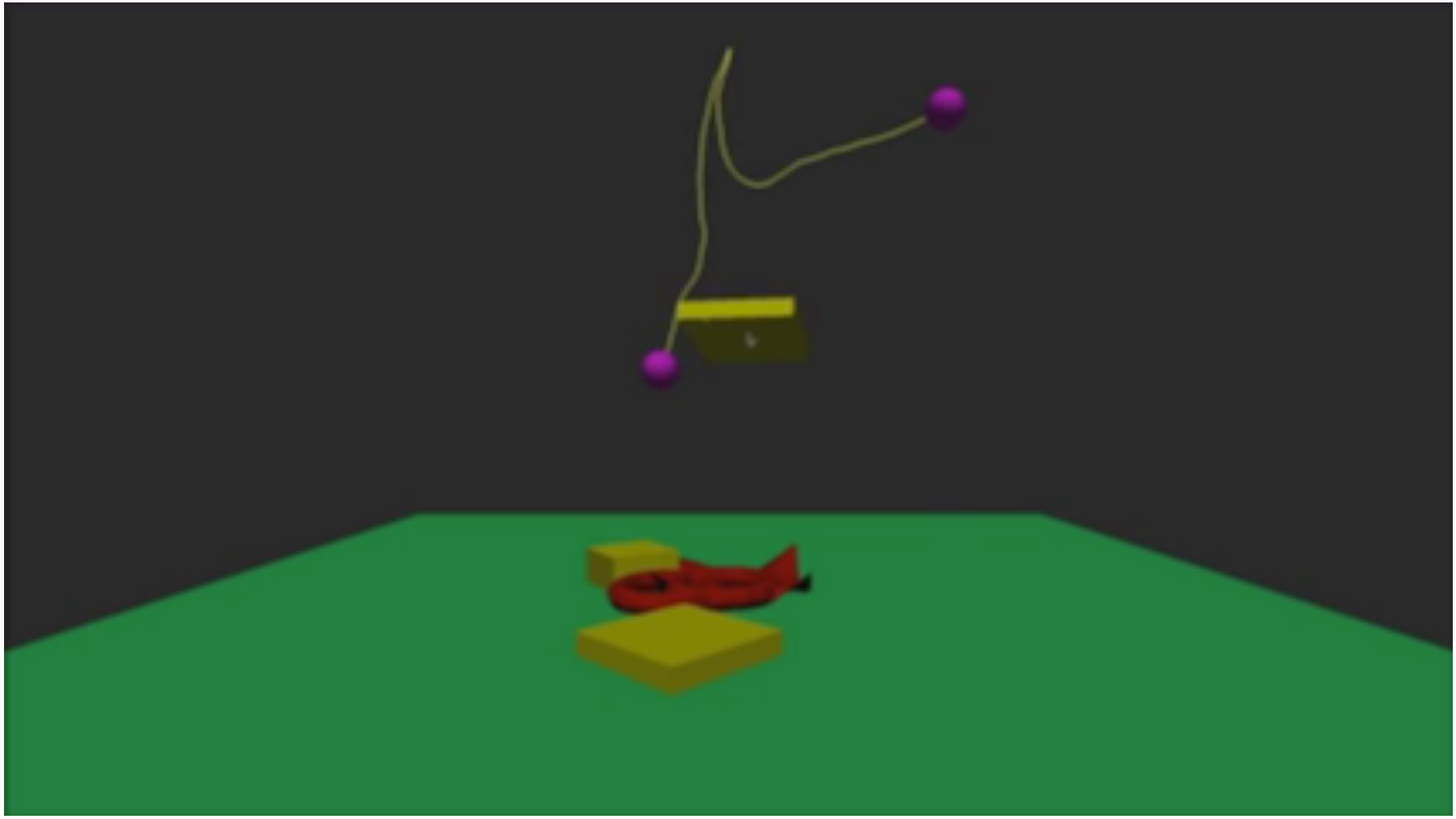
- Volume instead of point
- Handle collisions
- Position & orientation
- Tricky:
  - Collisions / stacking
  - Constraints



Rigid Bodies



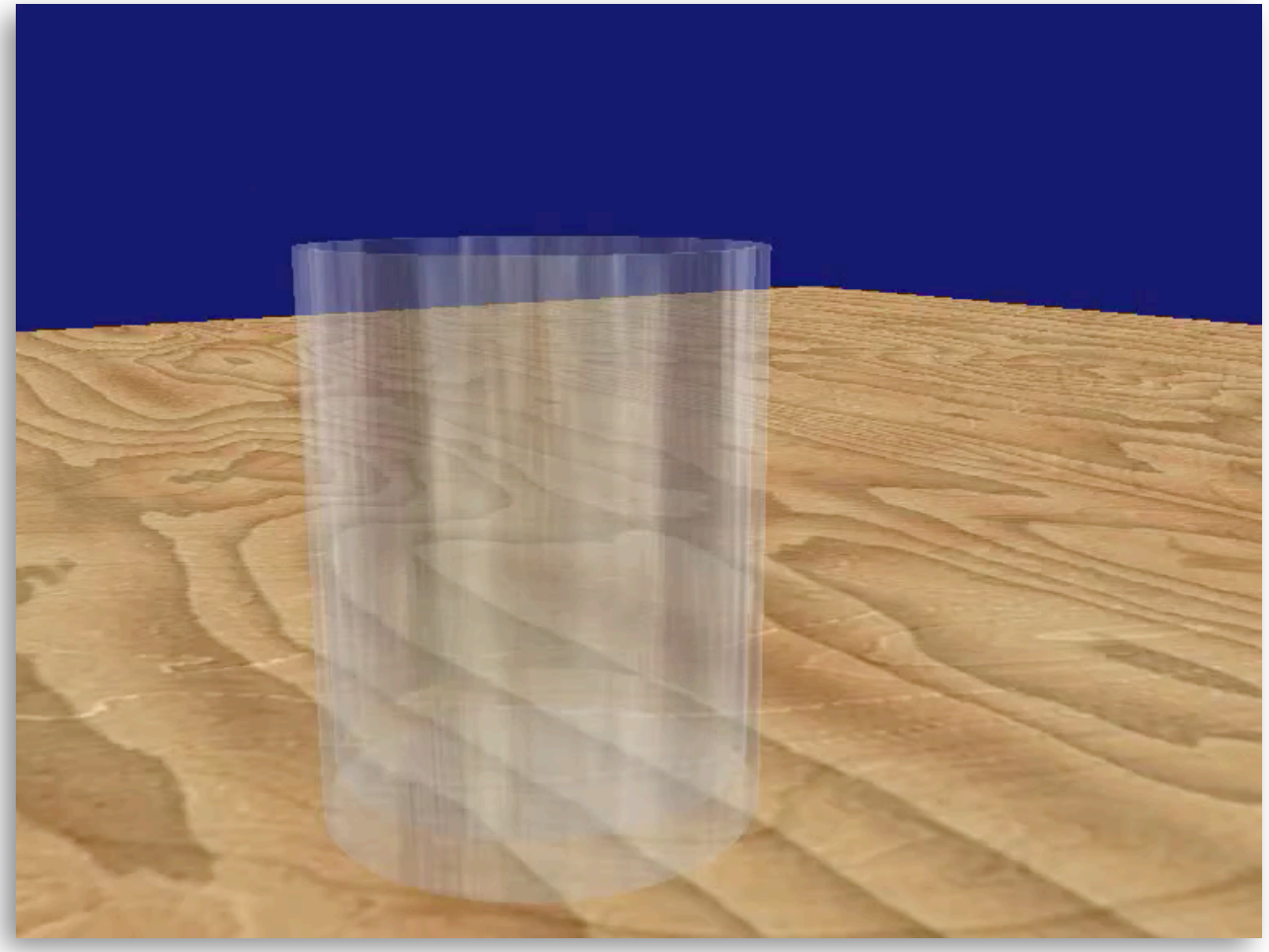
Rigid Body Engines (Bullet)



Fluids

- Deforming material
  - Different physical model necessary
- Lagrangian approach: SPH
- Lots of computations…

Particle-based Fluid Example

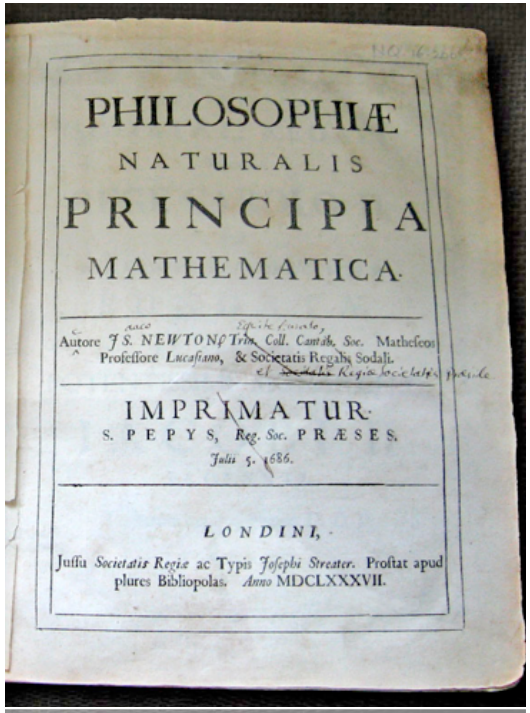


History

Physical Simulations

- Well known equations
  - Newton, 1660 *Motion*
  - Hooke, 1670 *Elasticity*
  - Navier/Stokes, 1822 *Fluids*

- Simulations made possible by computers
  - 1938: Zuse 1, 0.2 flops
  - 2008: Roadrunner, ca. 1 petaflop


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.
Autore J. S. NEWTONO Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.
IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.
LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

Goals & Challenges

- Scientific computations
  - Reproduction of real phenomena
  - Substitute for experiments

Different goals require different algorithms and representations!

- Physically-based animation
  - Imitation of physical phenomena, *visual* accuracy
  - Performance / stability constraints determine amount of realism

End