Physically-Based Simulation

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Group 16

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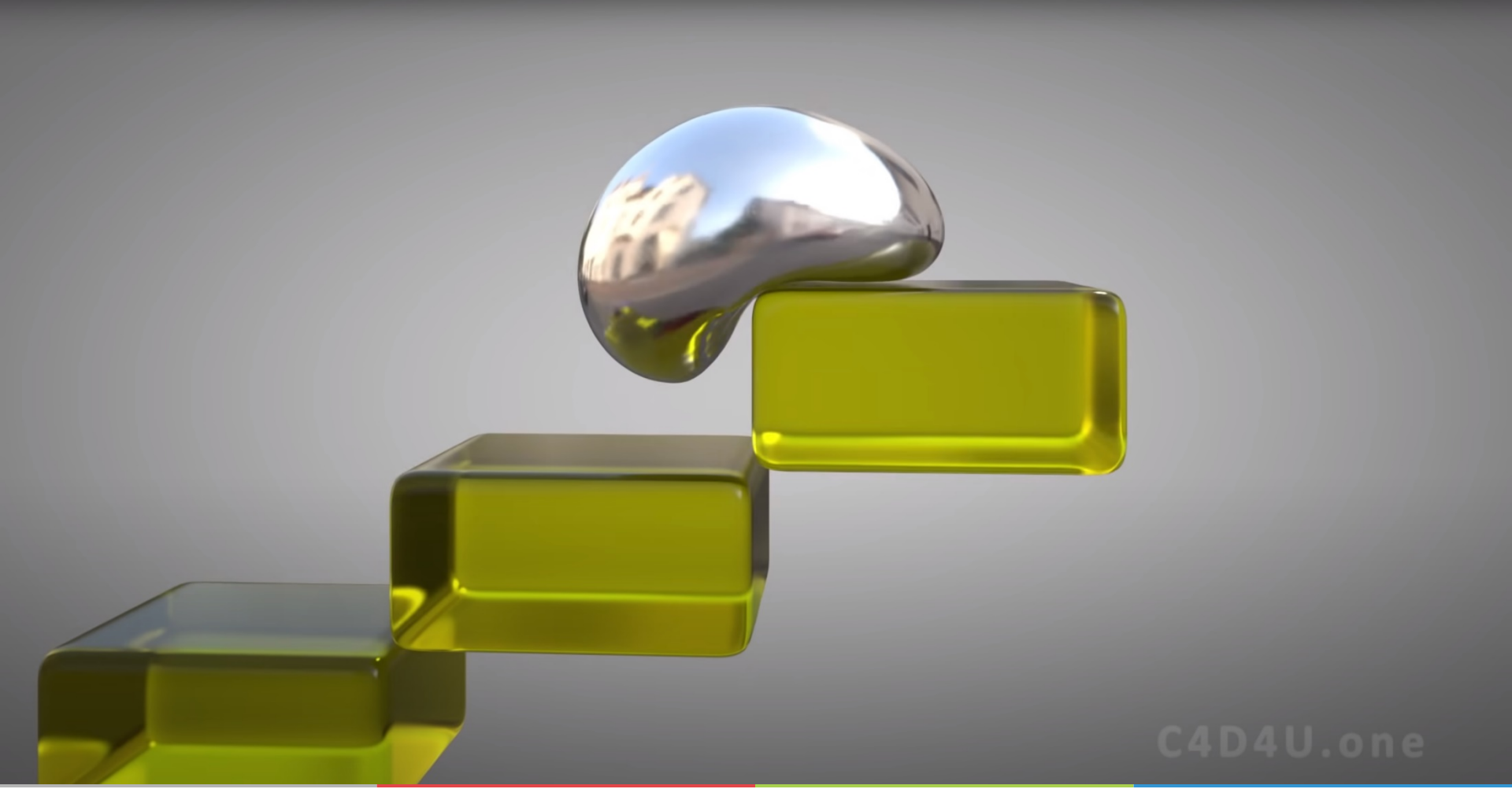
Simulation Scenario

- Soft body that interacts with a playground
- Motivation: create a beautiful simulation

Methods

- Finite-Element-Method, 3D, using tetrahedra,
- Collision detection and response to static rigid bodies

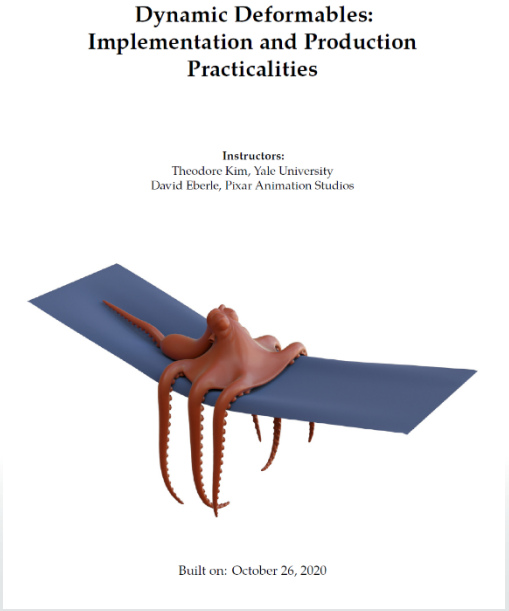


Christian Rehrmann, C4D4U, animation created + rendered using Cinema4D

References – FEM

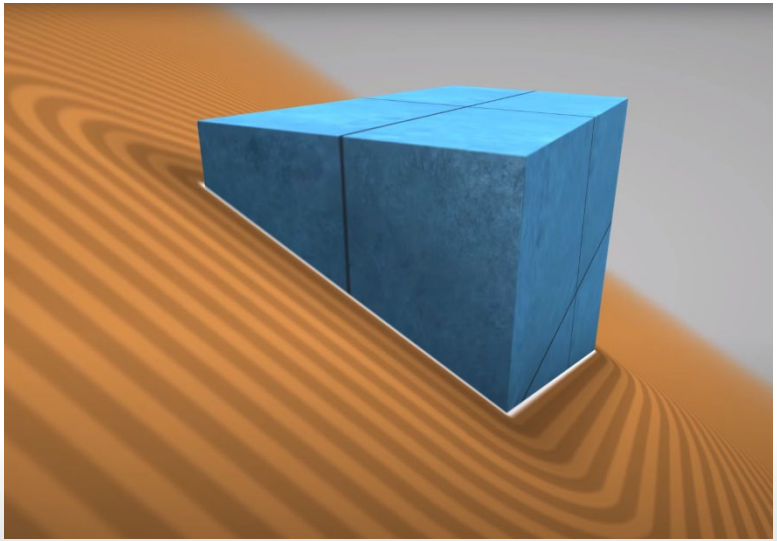
Baraff and Witkin 1998,
Large Steps in Cloth Simulation

Kim and Eberle 2020,
Dynamic Deformables



Reference – Playground

Inigo Quilez, Signed Distance Fields



$$n = normalize(\nabla f(p))$$

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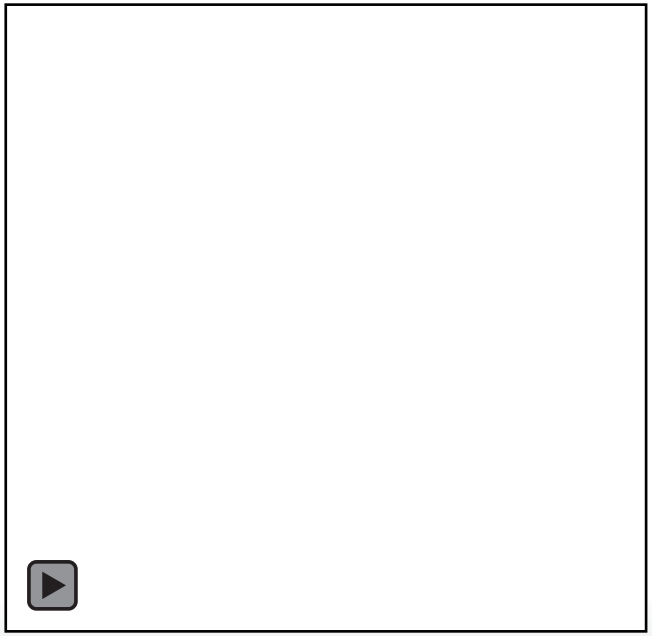
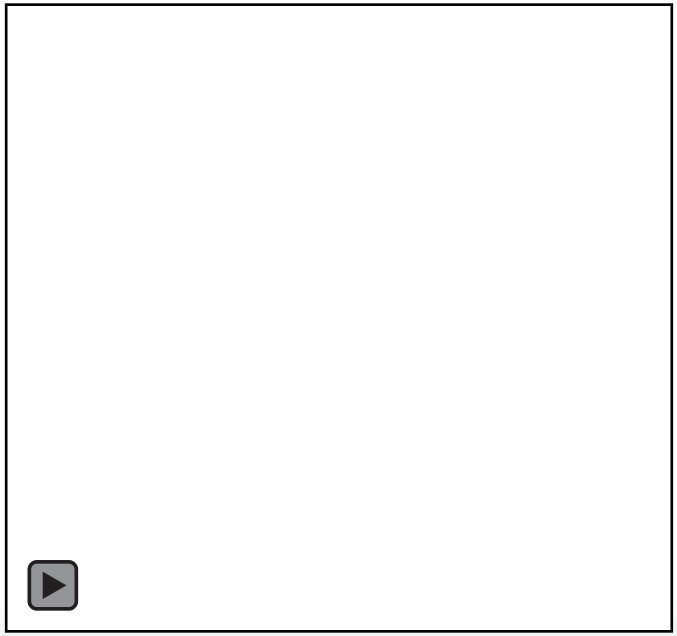
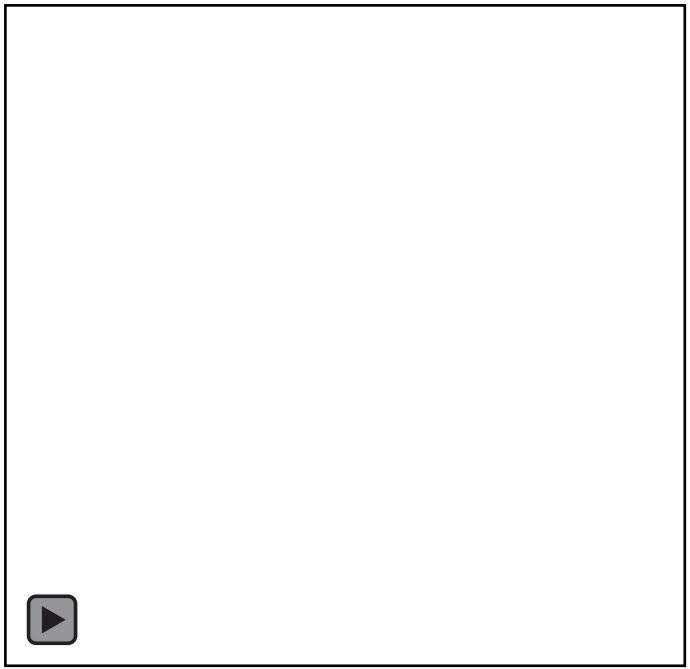
Implicit steps



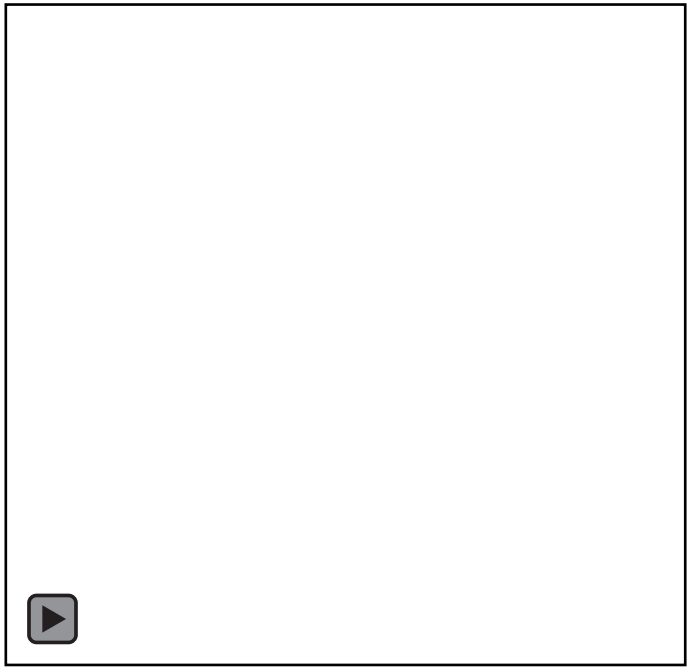


Explicit



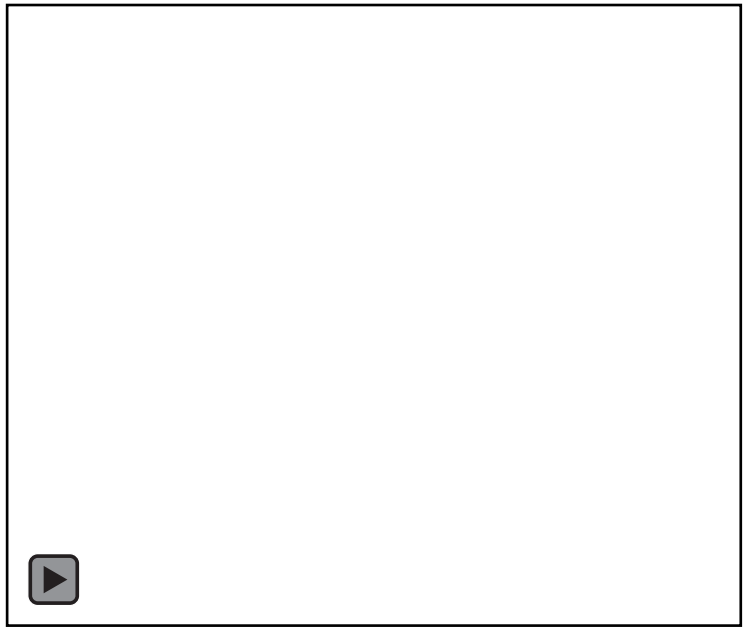
$$\frac{d}{dt}\begin{pmatrix}\mathbf{x}\\ \dot{\mathbf{x}}\end{pmatrix} = \frac{d}{dt}\begin{pmatrix}\mathbf{x}\\ \mathbf{v}\end{pmatrix} = \begin{pmatrix}\mathbf{v}\\ \mathbf{M}^{-1}\mathbf{f}(\mathbf{x},\mathbf{v})\end{pmatrix}$$

Implicit



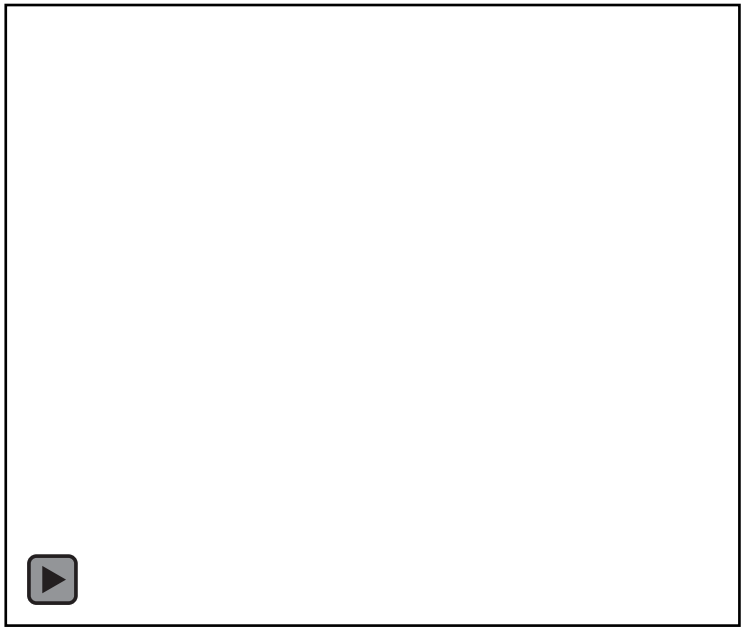
$$\begin{pmatrix}\Delta\mathbf{x}\\ \Delta\mathbf{v}\end{pmatrix} = h\begin{pmatrix}\mathbf{v}_0 + \Delta\mathbf{v}\\ \mathbf{M}^{-1}\mathbf{f}(\mathbf{x}_0 + \Delta\mathbf{x}, \mathbf{v}_0 + \Delta\mathbf{v})\end{pmatrix}$$

ARAP Energy



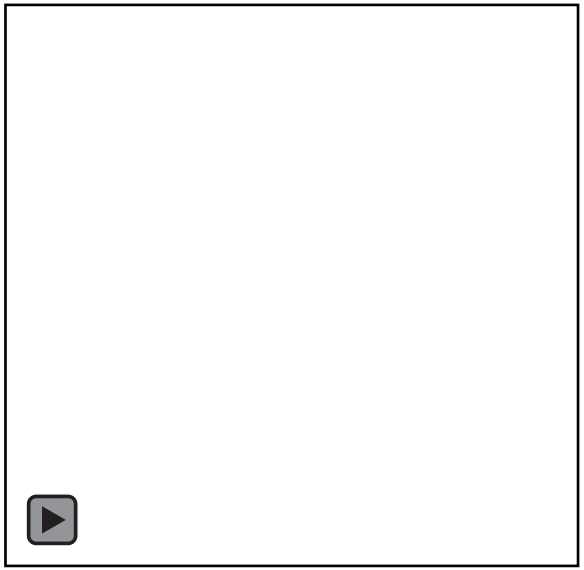
$$\mathbf{P}_{\text{ARAP}}(\mathbf{F}) = \mu(\mathbf{F} - \mathbf{R})$$

Neo-Hookean energy

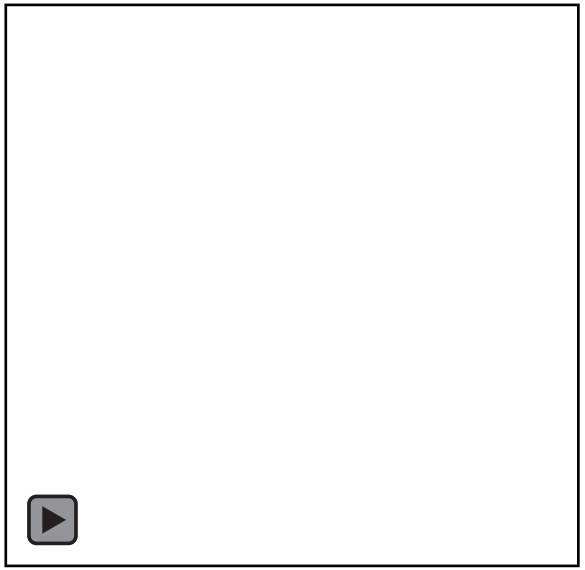


$$\Psi_{\text{BW08}} = \frac{\mu}{2}(\|\mathbf{F}\|_F^2 - 3) - \mu \log(J) + \frac{\lambda}{2}\left(\log(J)\right)^2$$

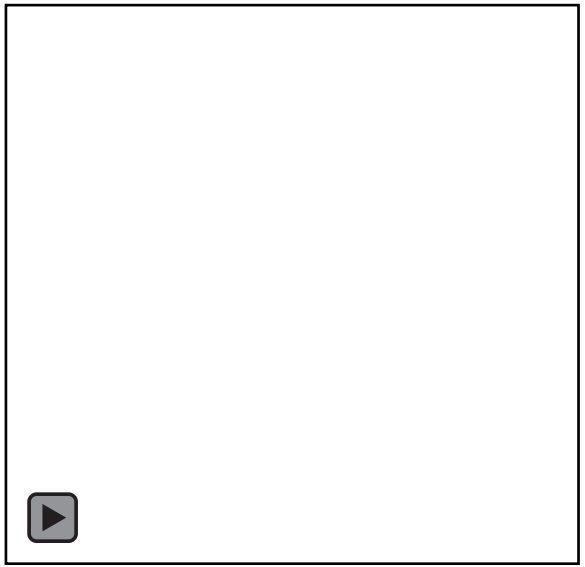
Parameters



μ = 5.0
λ = 5.0



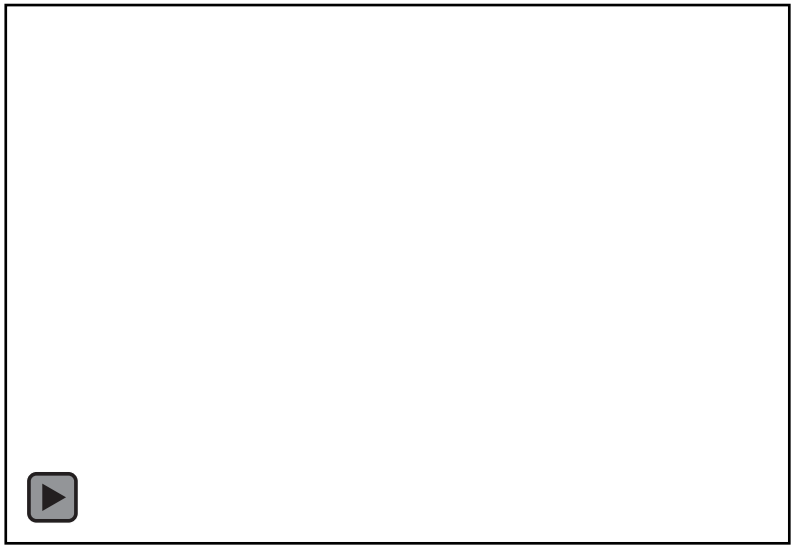
μ = 20.0
λ = 20.0

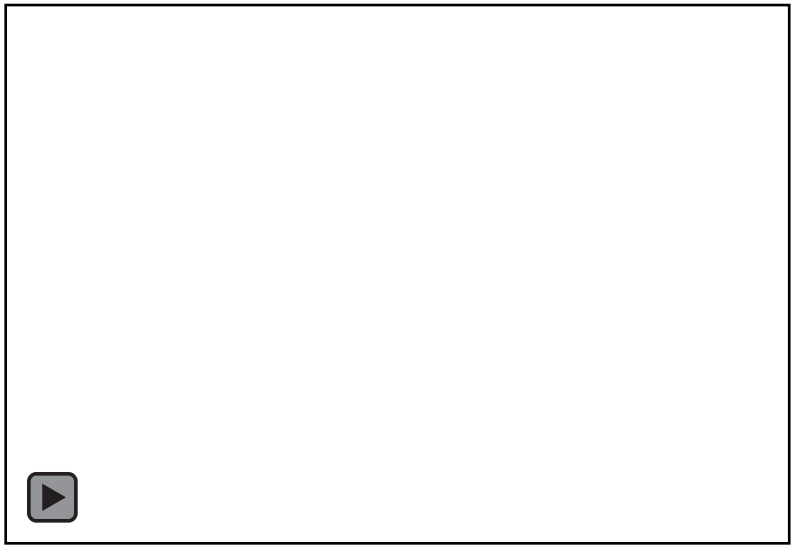


μ = 50.0
λ = 50.0

$$\Psi_{\text{BW08}} = \frac{\mu}{2}(\|\mathbf{F}\|_F^2 - 3) - \mu \log(J) + \frac{\lambda}{2}\left(\log(J)\right)^2$$

Parameters

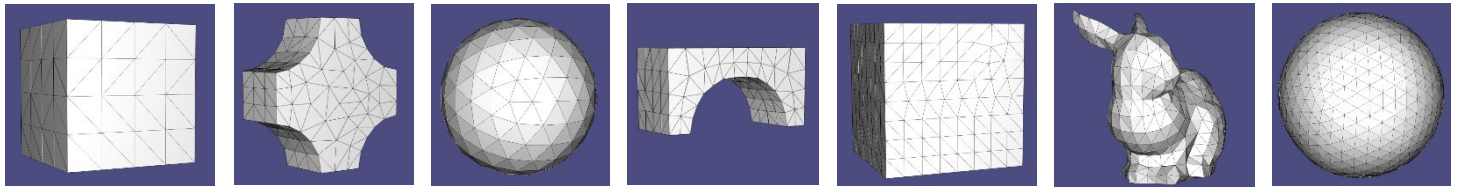




Mass = 0.1 kg/m^3

Mass = 1.0 kg/m^3

Performance

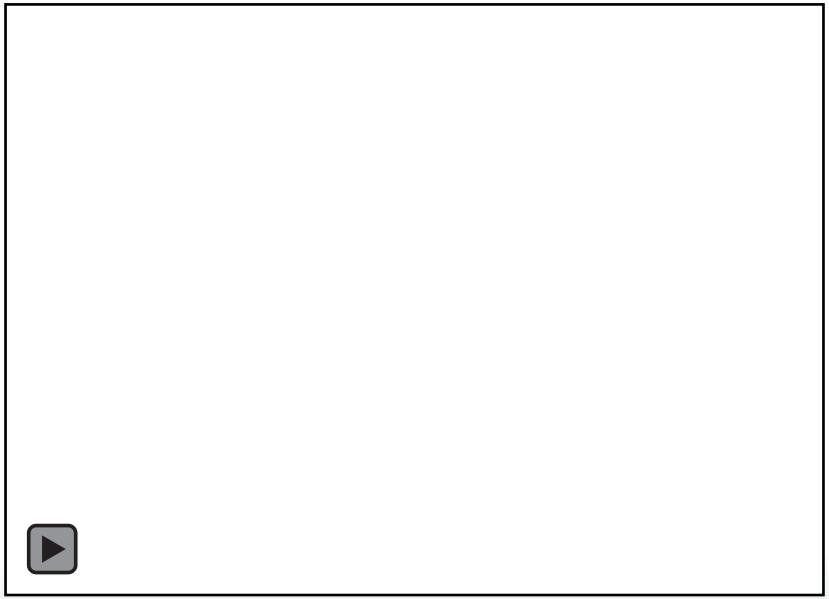


tetrahedra	234	471	504	531	1349	1711	2580
ms per iteration	4.11	7.65	9.02	9.85	38.41	45.65	102.40

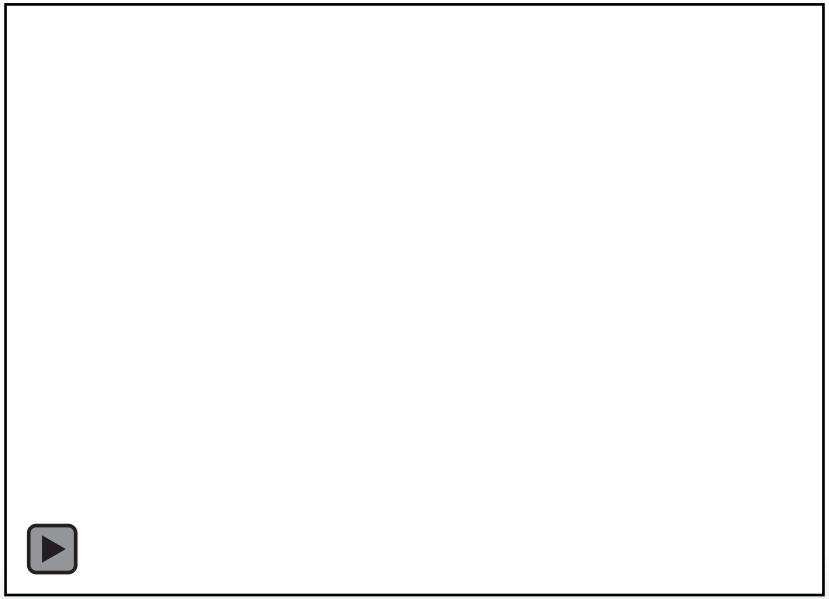
Stability

$$\mathbf{P}_{\text{ARAP}}(\mathbf{F}) = \mu(\mathbf{F} - \mathbf{R})$$

$$\Psi_{\text{BW08}} = \frac{\mu}{2}(\|\mathbf{F}\|_F^2 - 3) - \mu \log(J) + \frac{\lambda}{2}\left(\log(J)\right)^2$$

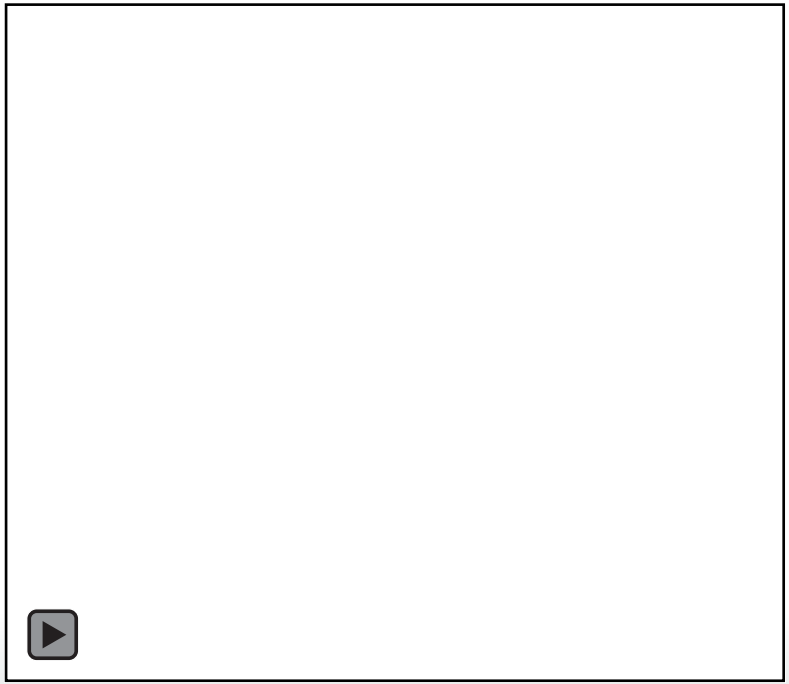


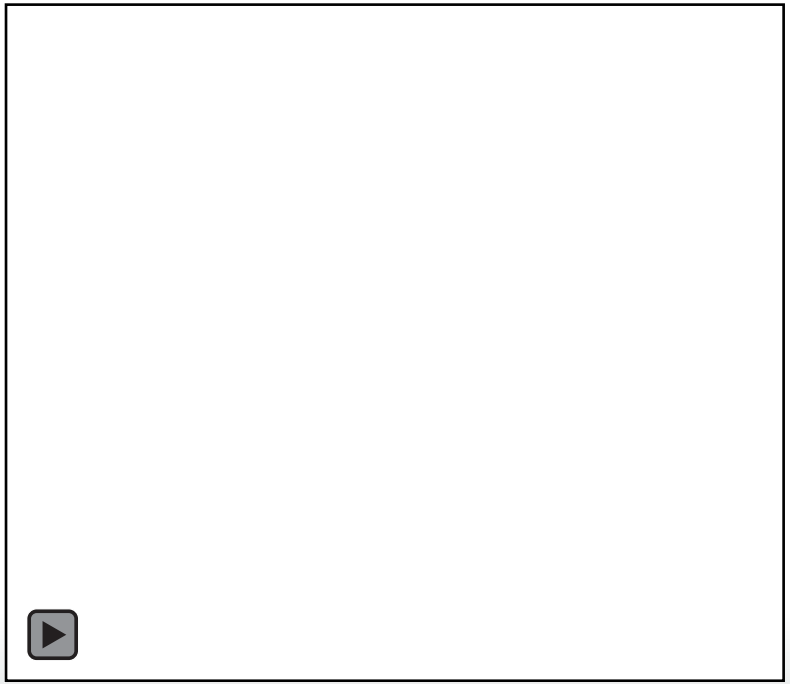
ARAP filtered – unconditionally stable



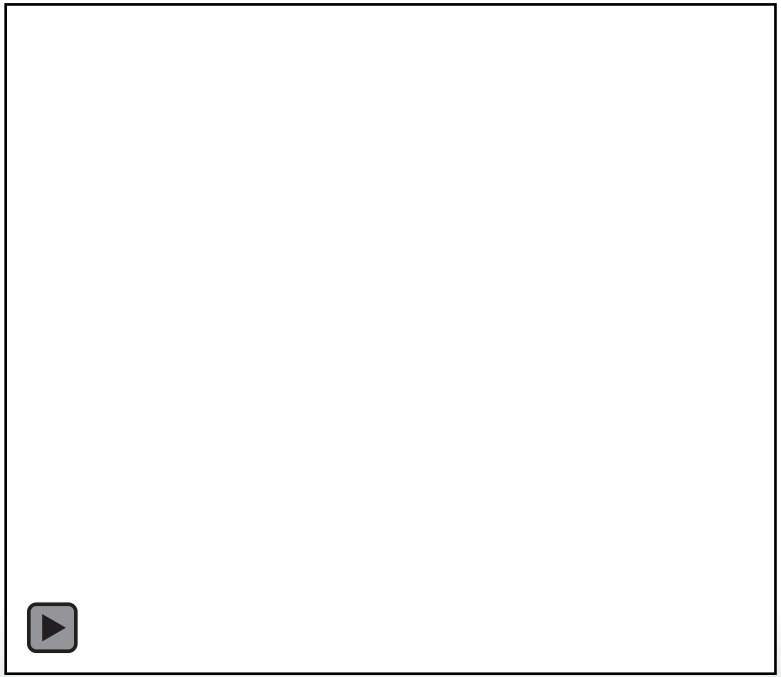
NeoHookean not filtered

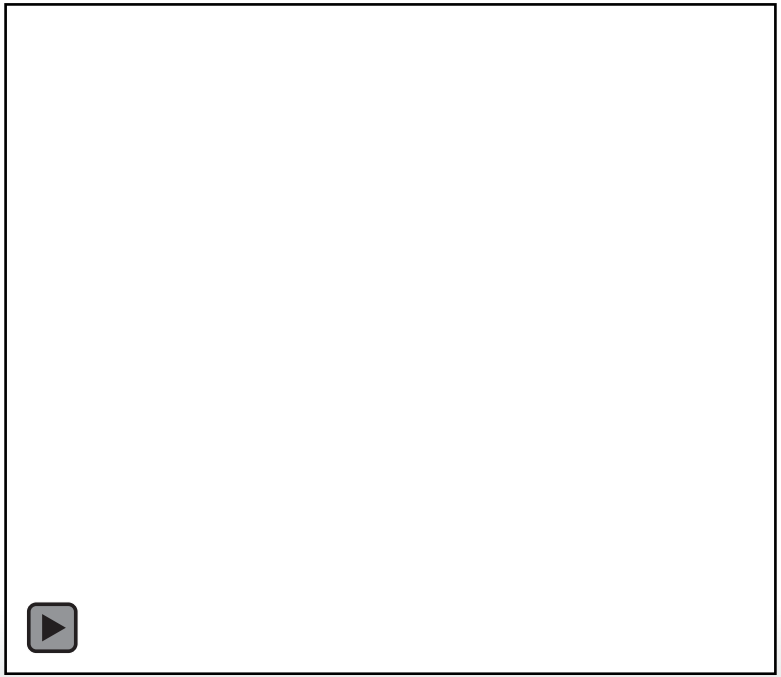
Gallery





Gallery





Accomplished targets

Implementation of various energies
Testing on various shapes
Basic playground
Stability for ARAP energy

Thank you