PhysGaussian: Physics-Integrated 3D Gaussians for Generative Dynamics

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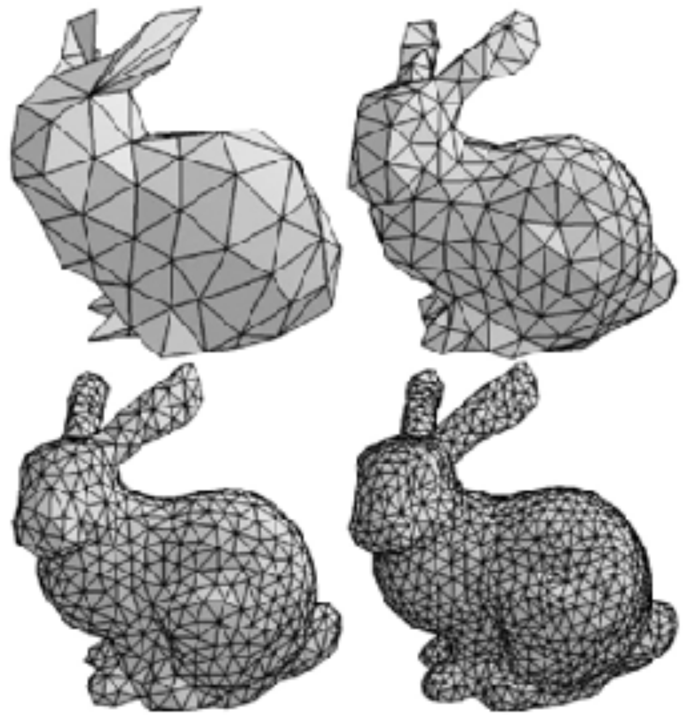
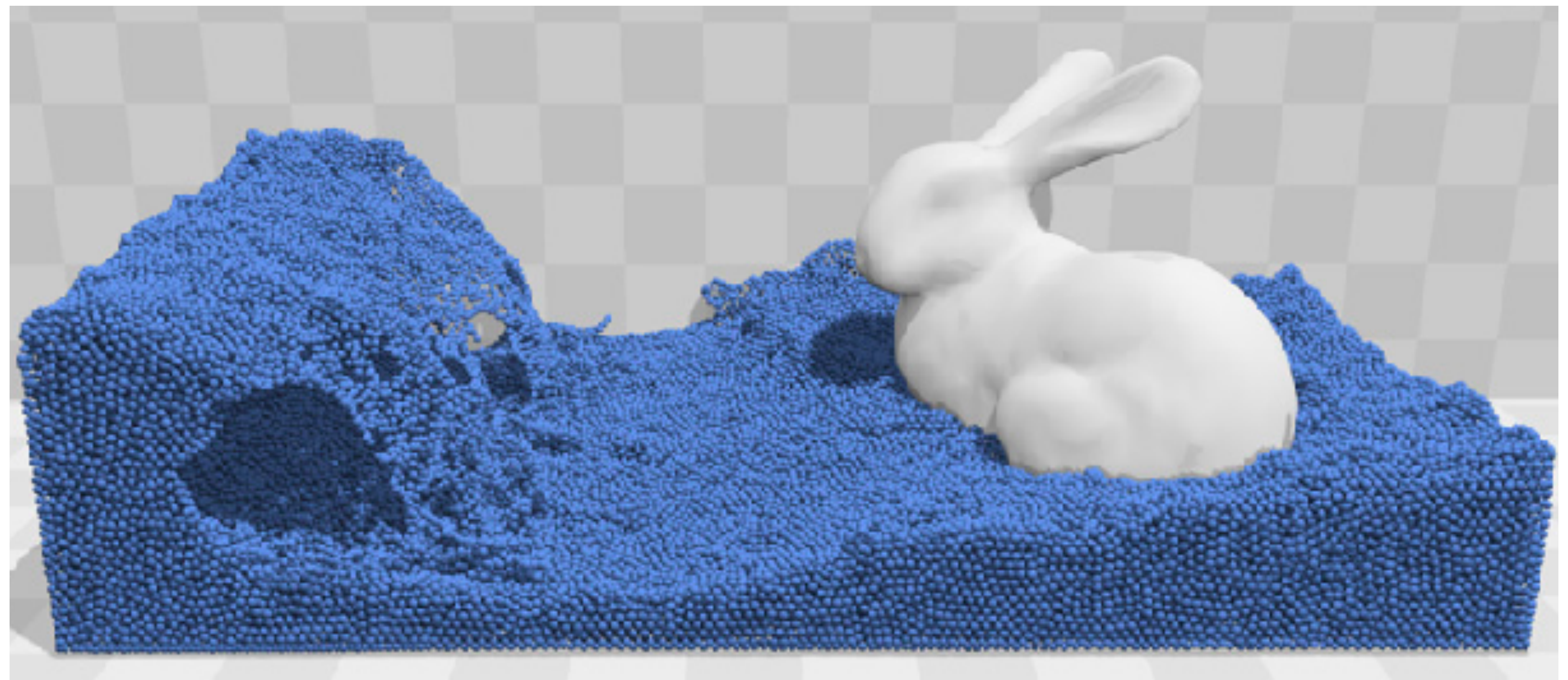
Traditional Physics-based Animation Pipeline

Real Object



Modeling



[Macklin et al. 2013]

Simulation

[Macklin et al. 2013]

Rendering

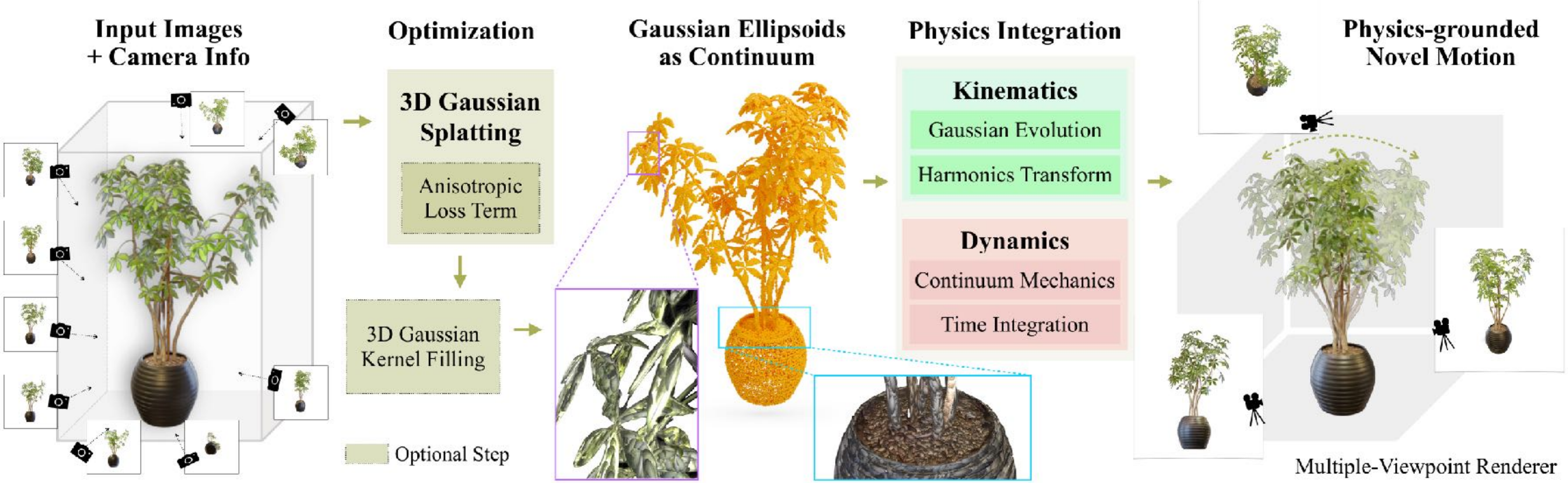
Task: Physics-aware Generative Dynamics

Multi-view Images

Physics-based Dynamics

Unified Modeling/Simulation/Rendering Pipeline

Method Overview



Modeling **Simulation** **Rendering**

What is Dynamics?

- Continuum mechanics describes motions by a time-dependent **deformation map**:

$$x = \phi(X, t)$$

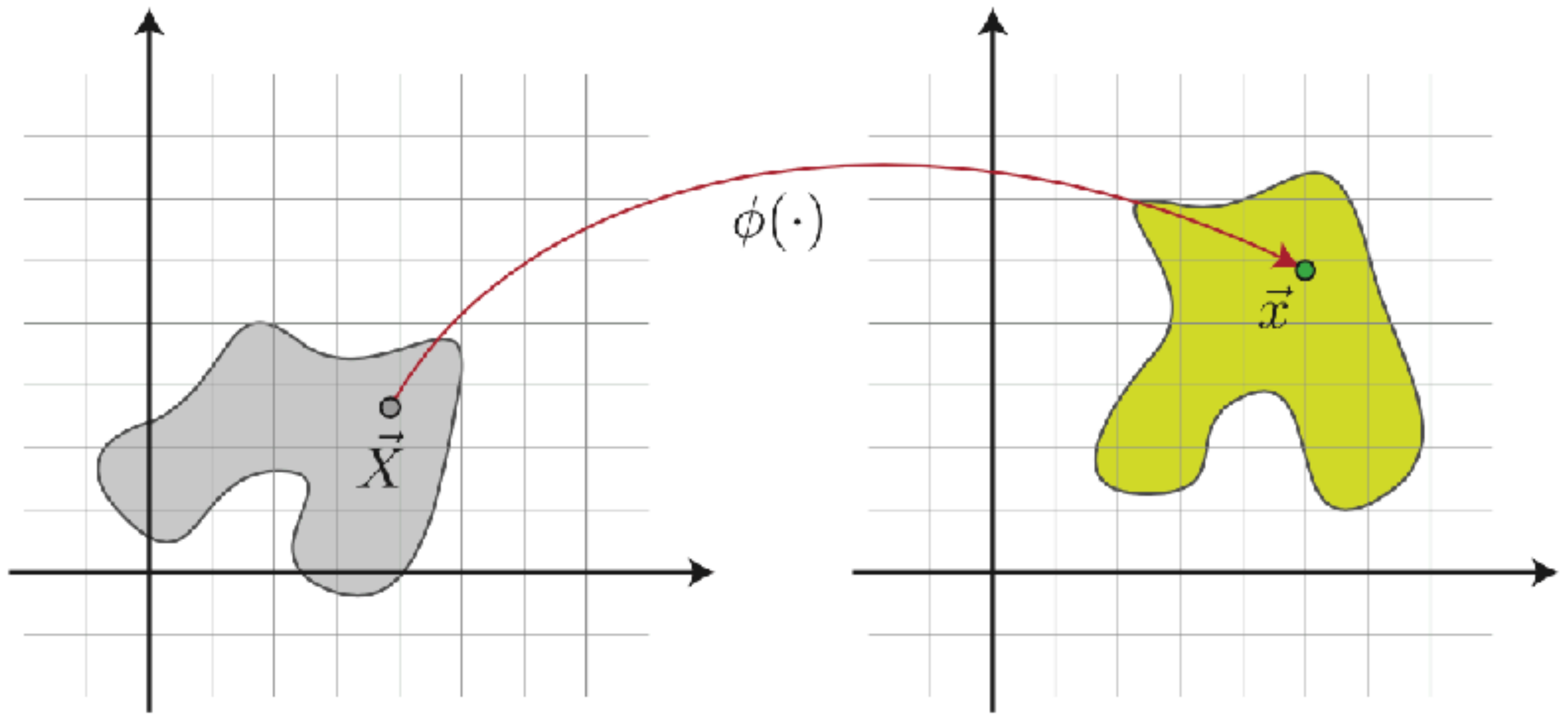
- The **deformation gradient** encodes the local transformations (**linearization**)

$$F(X, t) = \nabla_X \phi(X, t)$$

- The velocity change is governed by the **momentum conservation law**:

$$\rho(x, t)\dot{v}(x, t) = \nabla \cdot \sigma(x, t) + f^{ext}$$

Mass Acceleration Force



Material Space World Space

Per-point Newton Second Law

Evolving Gaussian Kernels

Rest Shape

$$G_p(X) = e^{-\frac{1}{2}(X-X_p)^T A_p^{-1}(X-X_p)}$$

Deformed Shape

$$G_p(x,t) = e^{-\frac{1}{2}(\phi^{-1}(x,t)-X_p)^T A_p^{-1}(\phi^{-1}(x,t)-X_p)}$$

Not Gaussian

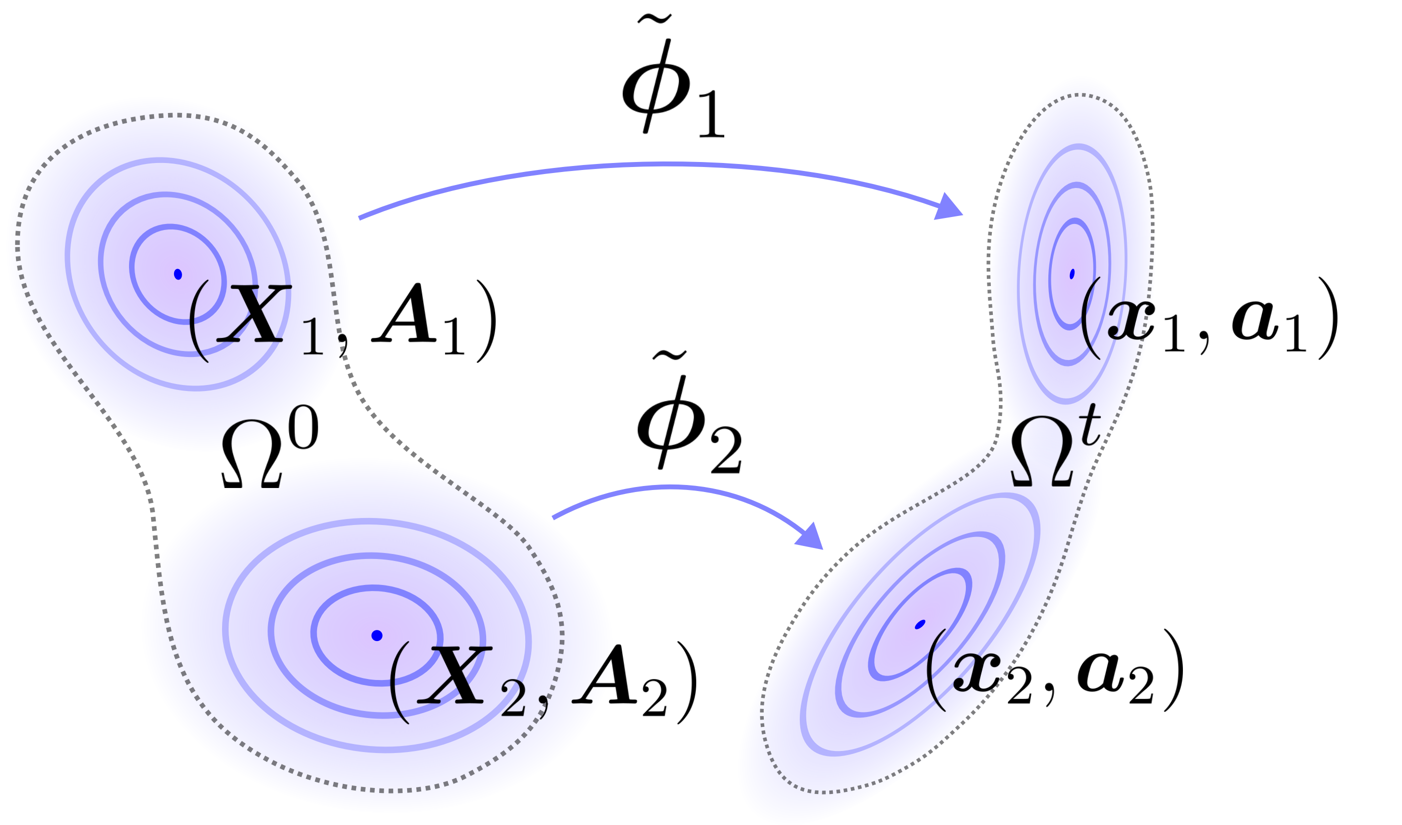
Assume local affine transformations (linearization):

$$\tilde{\phi}_p(X,t) = x_p + F_p(X - X_p)$$

$$G_p(x,t) = e^{-\frac{1}{2}(x-x_p)^T(F_pA_pF_p^T)^{-1}(x-x_p)}$$

Evolved Position x_p

Evolved Covariance a_p



$$x_p(t) = \phi(X_p, t)$$

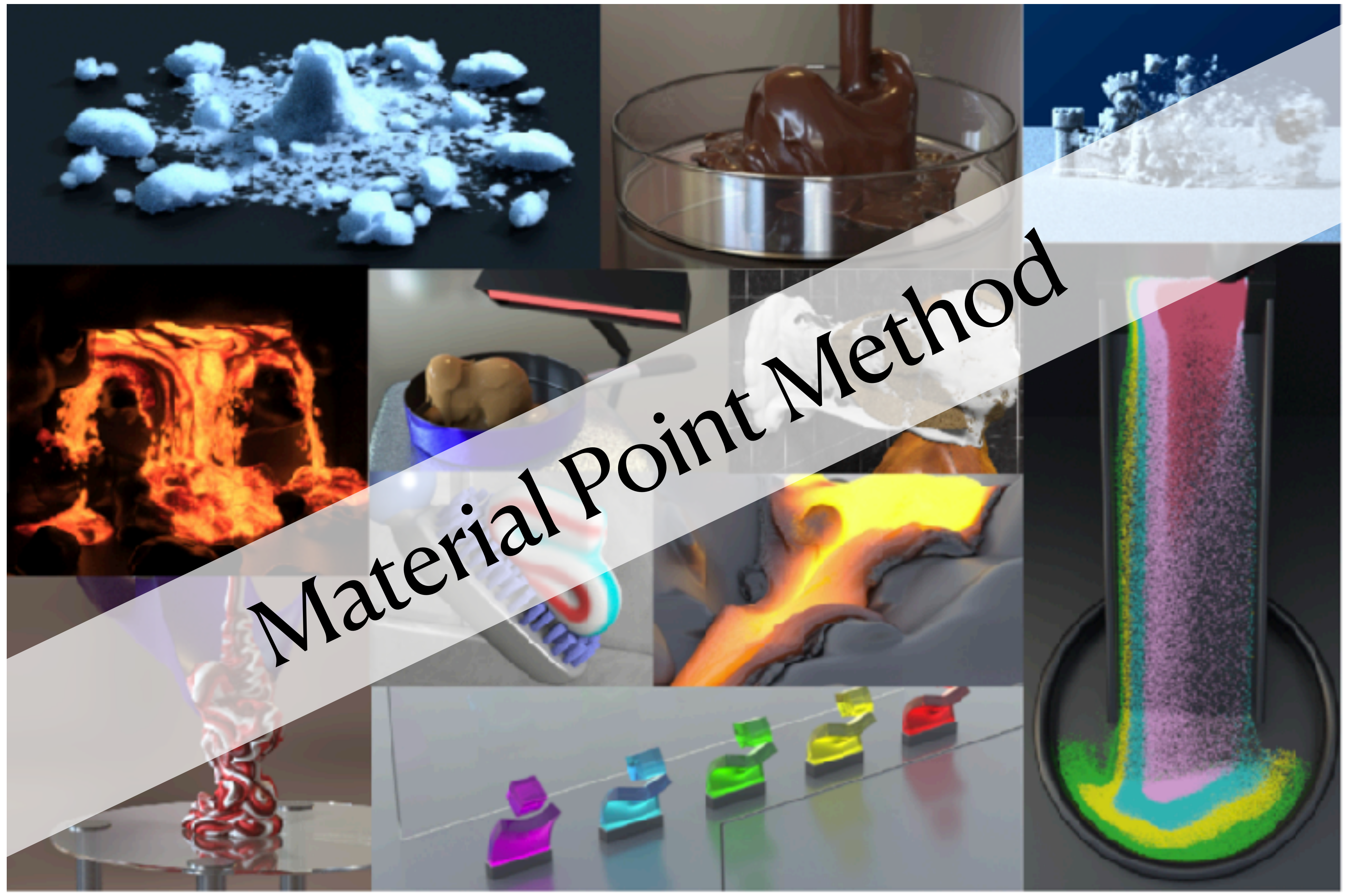
$$a_p(t) = F_p(t)A_pF_p(t)^T$$

Simulator Choice

Requirement:

- Use particles as the geometry discretization.
- Easily obtain deformation gradients on particles.
- Support vast types of dynamics.

The only choice:



Summary of Generative Dynamics

Modeling

→

Kinematics

Gaussian

Harmonics

Dynamics

Continuum

Time

Simulation

→

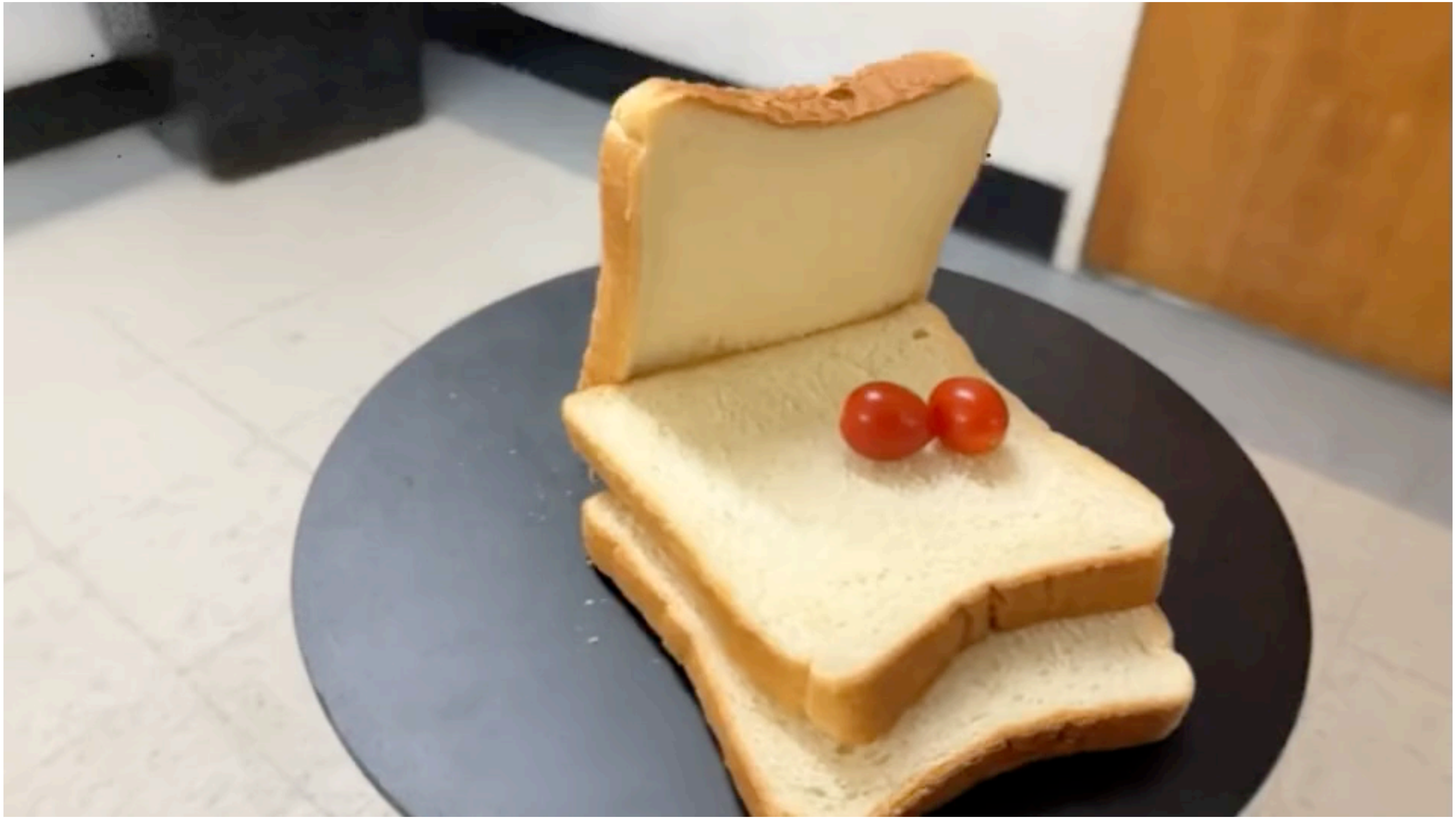
Rendering

Results

Fox (Elasticity)

Plane (Metal)

Toast (Fracture)



Ruins (Sand)

Jam (Paste)

TEAR TO SQUEEZE
DIP & SQUEEZE
HEINZ
TOMATO KETCHUP
TEAR TO SQUEEZE
DIP & SQUEEZE
HEINZ
TOMATO KETCHUP

Thanks!