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Peridynamics-Based Fracture Animation for Elastoplastic Solids

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1. Revision Summary

We have carefully revised our submission according to the suggestions of the reviewers. The major changes include (but not limited to):

1. Blablabla.

2. Answers to Reviewers' Comments

Here we respond to the comments made by each reviewer.

Reviewer #1:

Q: *More explicit discussion on damping in the paper is preferred.*

Blablabla.

Reviewer #2:

Q: *Limitations for meshing and explicit fracture comparison to other methods.*

Blablabla.

Reviewer #3:

Q: *How much does the interaction radius parameter* δ *affect the simulation quality?*

Blablabla.

Q: *There are missing steps for discretization. How do we go from equation 1 to discrete equations of motion, where* $\mathbf{x}$ *and* $\mathbf{x}'$ *are particles rather than arbitrary points in the material?*

Blablabla.

Q: *Can't the use of the weights defined in equation 4 be interpreted as just a discretization of divergence, except over the entire horizon rather than over an element neighborhood?*

To our minds, we do not think the weight function in Peridynamics amounts to a discretization of divergence in FEM. In fact, by comparing the governing equations in both theories, we could easily derive that the divergence of stress in FEM is equivalent to integration of force density over horizon, which is

$$\nabla \cdot \sigma = \int_{H_{\mathbf{x}}} [\mathbf{T}\langle \mathbf{x}', \mathbf{x} \rangle - \mathbf{T}\langle \mathbf{x}, \mathbf{x}' \rangle] dV_{\mathbf{x}'} \tag{1}$$

From discretization, we could naturally have

$$\nabla \cdot \sigma = \sum_{H_{\mathbf{x}}} [\mathbf{T}\langle \mathbf{x}', \mathbf{x} \rangle - \mathbf{T}\langle \mathbf{x}, \mathbf{x}' \rangle] V_{\mathbf{x}'} \tag{2}$$

We note that it is the force summation over horizon that should be interpreted as a discretization of divergence. Although weight functions are encoded in force density, ω is used only to compute the force summation in a weighted way, which is inherently different from other methods such as SPH where weight functions are simutaneously used to calculate quantities' first-order or second-order derivatives (e.g. $\nabla \cdot \mathbf{A_i} = -\frac{1}{\rho_i} \sum_j (\mathbf{A_i} - \mathbf{A_j}) \cdot \nabla \omega_{ij}$)

That is, in our formulation, what involved here are just displacements of material points, instead of the spatial derivative of the displacements, which consequently lead to the biggest difference between Peridynamic and other mesh(FEM) or meshless method.

In addition, ω is only associated with positions in reference space, rather than positions in deformed space, so we could pre-gurantee its value rationality by appropriately populating our material points in advance.

Q: *Correction for typos.*

Blablabla.

Q: *Lack discussion for XFEM-based methods in the related work.*

Blablaba.

Q: *How is equation 17 used, exactly? what are "rest_bond_num" and "initial_bond_num" in the definition of* ϕ*?*

Equation 17 amounts to the cauchy stretch with plastic deformation reasonably excluded, then we further improve it to Equation 18 by incorporating the weight function and increasing critical value through ϕ as fracture proceeding. "rest_bond_num" is the rest active bonds during fracture and "initial_bond_num" is the initial total bonds before fracture. We have modify this part of statements in the paper to make it more clarified.

Q: *Unreasonable statements about the relationship between*

rotation artifacts, geometric linearity and stress-strain linearity.

Blablabla.

Q: *How many elements were used for each example? How did the performance compare to the performance of peridynamics?*

Since we position our particles to the center of elements, the elements and the particles are of the same size in our simulations. We did't detailly compare the performance between FEM and Peridynamics, considering it could be affected by a lof of factors such as integration method and implementation, but we found in our experiments that the efficients of these two method are comparable.

Q: *Question on the supplemental video (random cube)?*

Blablabla.