CS 384G

Final Project - Fracturing & Deformation

Zack Misso & Ben Lin

Concept

We simulate the fracturing and deformation of objects via peridynamics and mass spring models.

Peridynamics

Peridynamics is a mathematical theory for modeling deformations while allowing the existence of discontinuities within a system. In a peridynamic system, objects are modeled as a collection of point masses where each point mass is connected with every other point mass within some horizon by stiff bonds. The force density within the object at some point x becomes dependent on the bond stretch for all bonds within its horizon, thus making the force density at a point also dependent on the overall deformation of the object around that point. Bonds within a peridynamic system can be thought of and represented as elastic springs. A peridynamic system is also meshless, meaning all the system needs is to know how particles within the system interact with one another. Discontinuities, or fractures, arise as bonds are broken due to them stretching past some critical stretch that is usually a function of the material.

Peridynamic Model:

Integral Form:

$$\rho\,\ddot{\boldsymbol{u}}(\boldsymbol{x},t) = \int_H \boldsymbol{f}(\boldsymbol{u}(\boldsymbol{x}',t) - \boldsymbol{u}(\boldsymbol{x},t), \boldsymbol{x}' - \boldsymbol{x})\,dV' + \boldsymbol{b}(\boldsymbol{x},t)$$

Discrete Form:

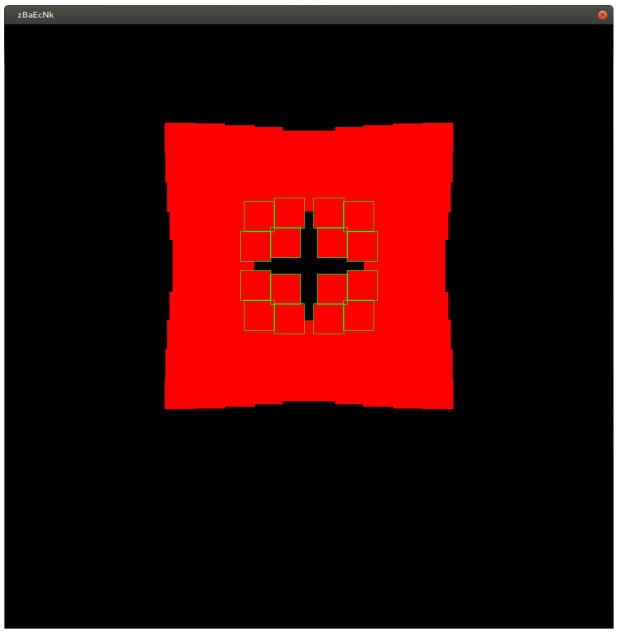
$$\rho \ddot{\boldsymbol{u}}_i^n = \sum_{k \in H} \boldsymbol{f}(\boldsymbol{u}_k^n - \boldsymbol{u}_i^n, \boldsymbol{x}_k - \boldsymbol{x}_i)\Delta V_i + \boldsymbol{b}(\boldsymbol{x}_i, t)$$

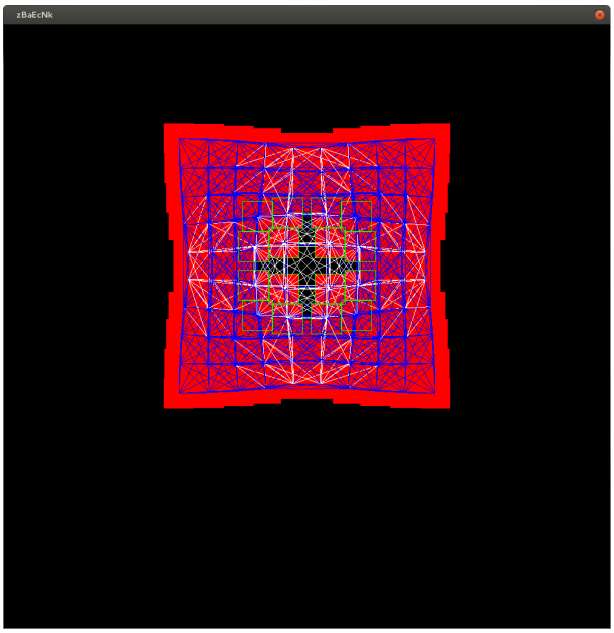
Our Implementation

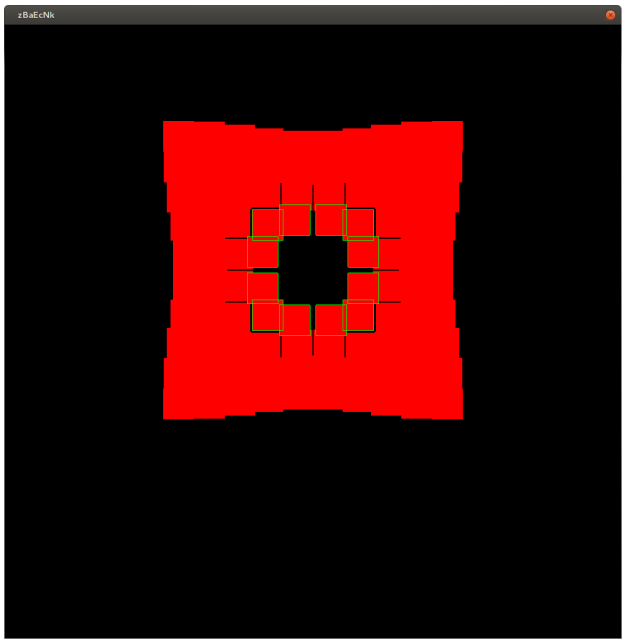
We implemented a peridynamics system to describe the material of objects and how they react during collisions with rigid bodies, or how they react when they have an immediate large force acting upon portions of the system. Collisions are detected between the peridynamic system representation of the object and rigid bodies by simple bounding box comparisons since the peridynamic system is just a collection of point masses represented as axis aligned bounding boxes. Collision Resolution is handled by the introduction of stiff springs between objects that have collided and the points of contact between the objects. We first define the space our peridynamic system exists in, and voxelize that space to create the point masses that make up the peridynamic system. Depending on the complexity of the simulation we were running, we arbitrarily chose the values of the constraints and time step to achieve the best looking results. In the future we plan on trying to mimic the properties of real world materials.

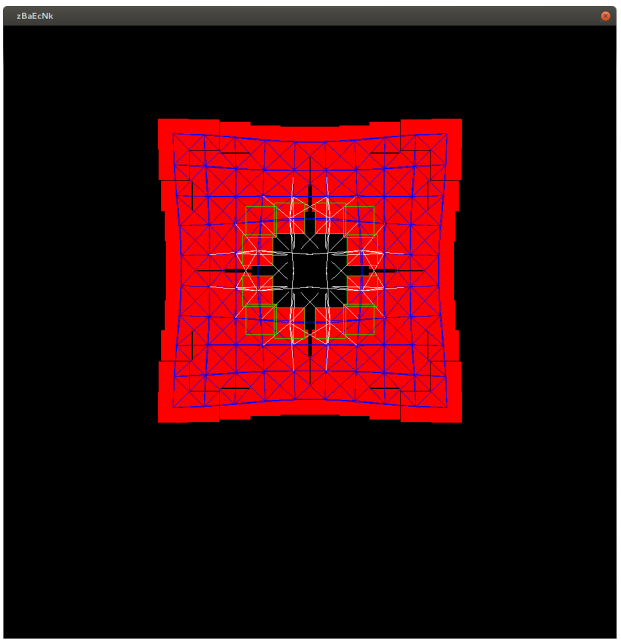
Results:

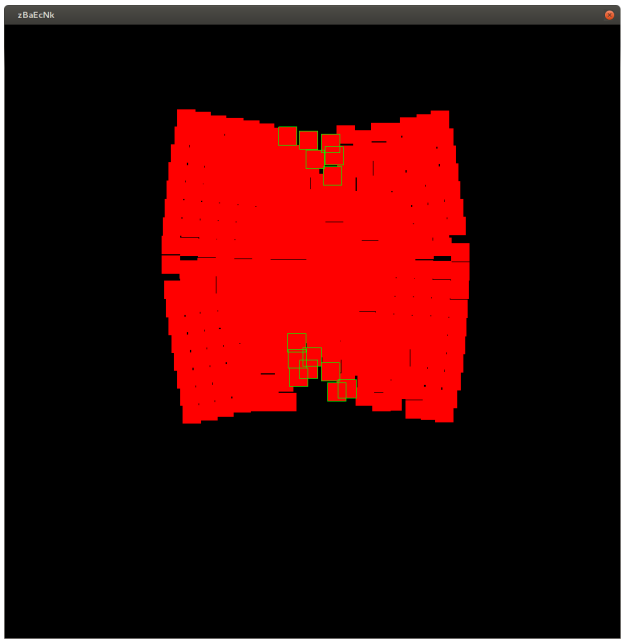
Orthographic Views were chosen because they looked the best. Green Blocks were point masses that were given a large initial impulse to result in fracturing. Blue lines represent springs. White lines represent broken springs.

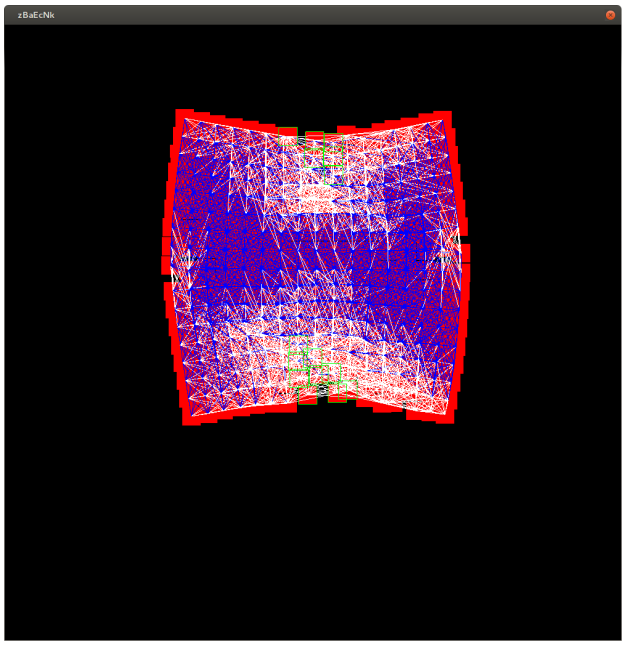

zBaEcNk

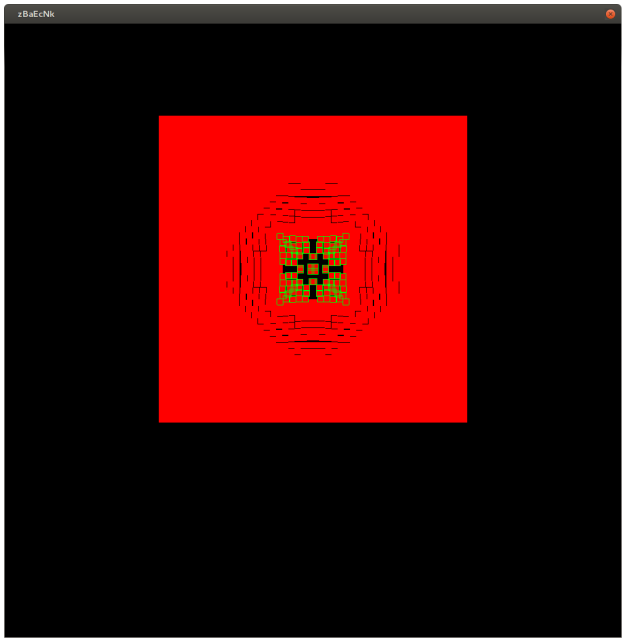

zBaEcNk

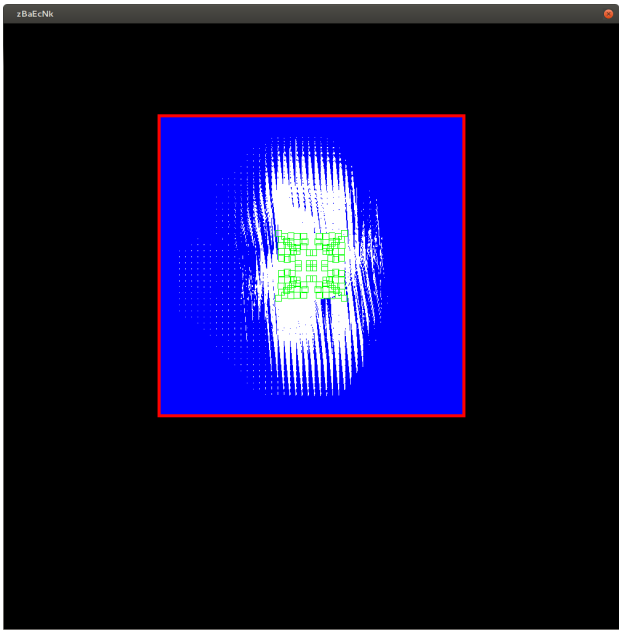

zBaEcNk

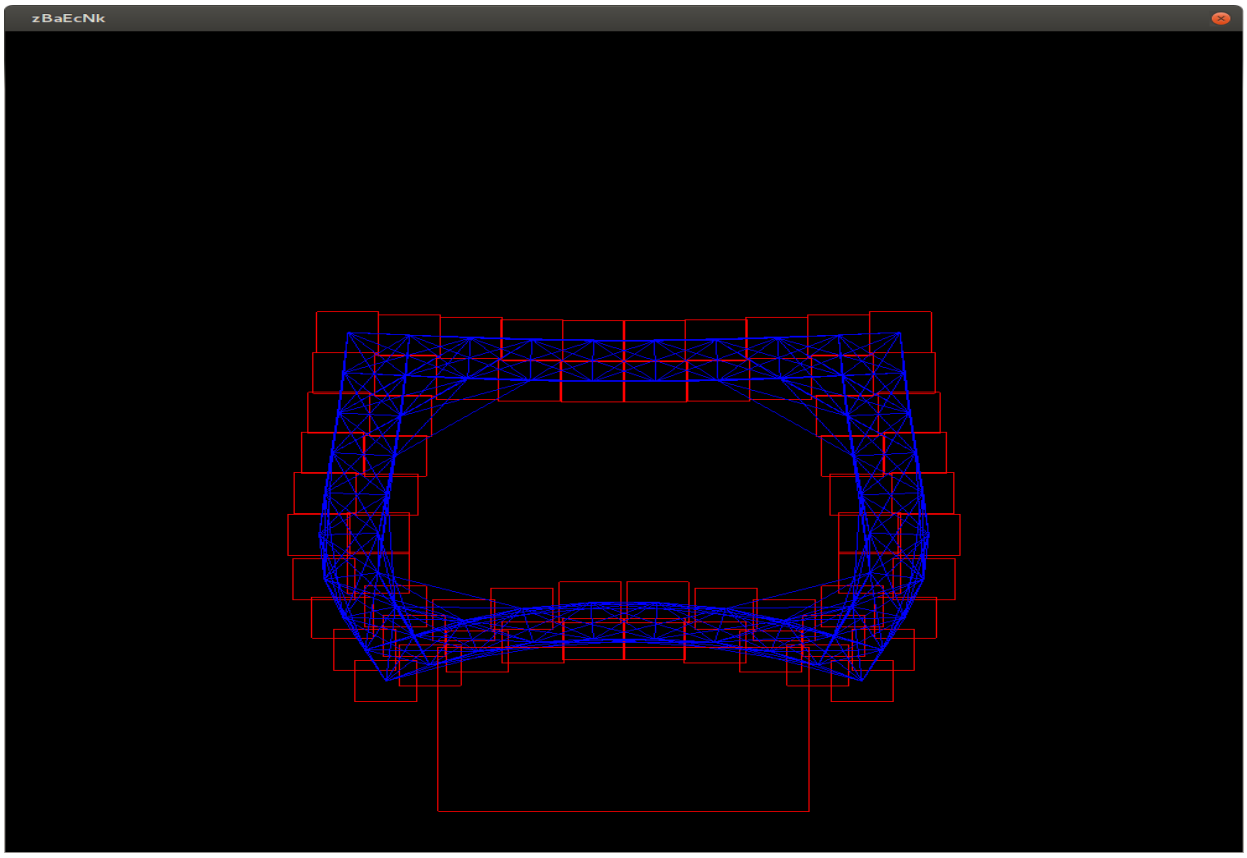

zBaEcNk


zBaEcNk


zBaEcNk


zBaEcNk


zBaEcNk



Future Extensions

Try to simulate real world materials. Currently we are arbitrarily choosing constants for our material and spring constants. It would be interesting to try to model real world materials such as wood or steel.

Improve Collisions. Currently our spring resolution suffers from sinking over time and, because of our lack of handling self collisions in peridynamic objects, the bond forces make impulse resolution hard to handle by only using spring based methods.

Voxelize real 3D models for simulations instead of just voxelizing axis aligned bounding boxes.

Rebuild mesh after simulating physics instead of only displaying the voxelized mesh.

Self Collisions within peridynamic objects after pieces have fractured off.

Apply our peridynamic system with objects that do not have a uniform material.

Apply same fracturing process to cloth to model tearing

Source Code

https://github.com/ZackMisso/GradGraphicsFinalProject

References:

[1] S. A. Silling, M. Epton, O. Weckner, J. Xu, and E. Askari, “Peridynamic States and Constitutive Modeling,” *J Elasticity*, vol. 88, no. 2, pp. 151–184, Jul. 2007.

[2] S. A. Silling and P. Demmie, “Peridynamic Simulation of High-Rate Material Failure,” 2007 ASME Applied Mechanics and Materials Conference, Austin, TX, 06-Jun-2007.

[3] M. L. Parks, R. B. Lehoucq, S. J. Plimpton, and S. A. Silling, “Implementing peridynamics within a molecular dynamics code,” *Computer Physics Communications*, vol. 179, no. 11, pp. 777–783, Dec. 2008.