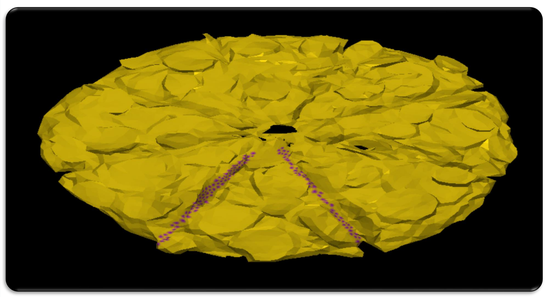
Artist Controlled Fracture Design Using Impurity Maps

Problem

- Fracture is a complex physical phenomena to simulate.
- Artistic control of fracture on any object is a very challenging problem.
- Maintaining physical realism in the presence of different material properties, makes it even harder.

Solution

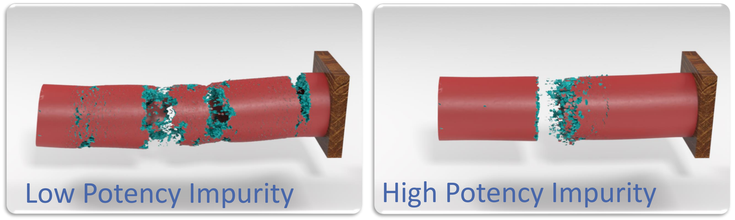
- An interactive framework that allows an artist to design the fracture pattern that appears on simulation.
- Works with both brittle and ductile materials.
- The artist controls a virtual sculpting tool to create an impurity map on an object.
- When the tool intersects the edges of the graph, impurities get added to the nodes.



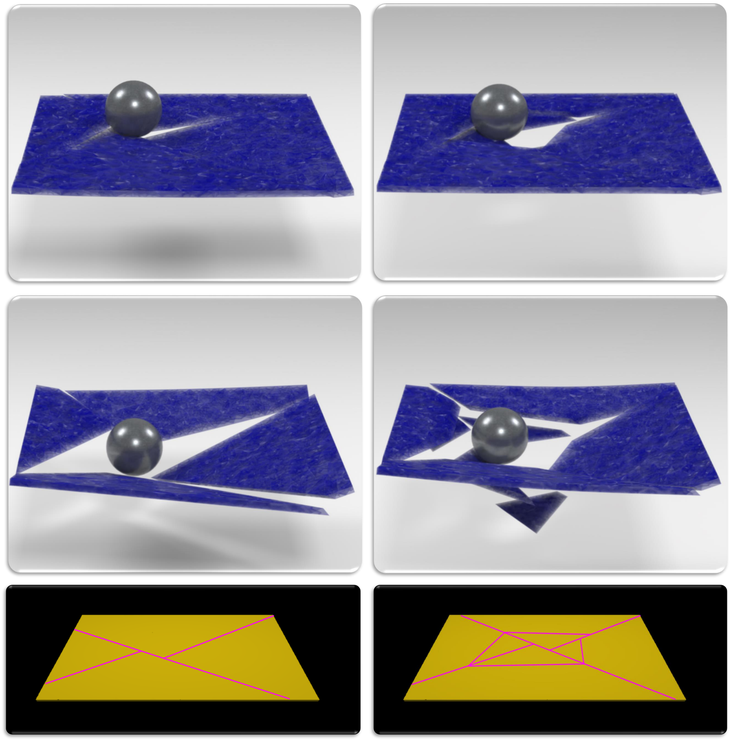
Artist designed impurity map on the pizza model.

Results

The pizza breaks according to the impurity map during simulation. The bits of cheese stretch correctly across the break. This is artist controlled ductile fracture.



Varying the potency of the impurity leads to different fracture behaviour for the same impurity mask.



Artist created impurity maps shown above guide the evolution of brittle fracture in a glass slabs that breaks on impact during simulation.

Random graph-based impurity maps, allow artists to selectively weaken parts of an object and thus produce controlled fracture patterns in complex objects.

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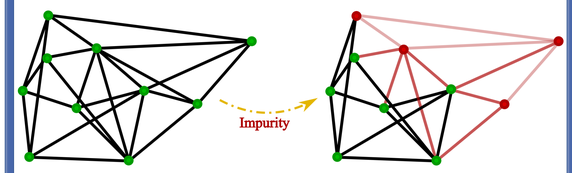
Method

- We develop novel random graph-based [1] impurity maps to guide fracture paths.
- Fracture is simulated using graph-based FEM [2][3]



- As state or condition of material affects the fracture propagation, we selectively weaken a material by corrupting it with impurities along artist directed paths or regions.
- Probability of removing an edge between nodes i and node j is given by

$$p_{ij} \propto \left\{1 - h\left[2\left(d_i + \frac{1}{|\alpha_i|}\right)\left(d_j + \frac{1}{|\alpha_j|}\right)\right]\right\}$$

- α_k is the potency of the impurity. It decides how clean the cut or fracture is.

References

1. B. Pittel. On a Random Graph Evolving by Degrees. Advances in Mathematics 223, 2 (2010), 619-671.
2. P. Khodabakhshi, J. N. Reddy, and A. Srinivasa. GraFEA: A Graph-based Finite Element Approach for the Study of Damage and Fracture in Brittle Materials. Meccanica 51 (2016), 3129-3147.
3. A. Mandal, P. Chaudhuri, and S. Chaudhuri. Remeshing-Free Graph-Based Finite Element Method for Ductile and Brittle Fracture. (2021) arXiv:cs.GR/2103.14870