Research Statement

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I am a PhD candidate at the Indian Institute of Technology Bombay, India expecting to graduate in June 2023. My research centers around physics-based animation with a focus on mesh-based fracture simulation. I am writing to express my interest in a postdoctoral position in your lab.

During my PhD, I investigated various aspects of physics-based realistic fracture simulation. Existing fracture simulation algorithms [1] [4] incur additional computational costs for each new crack discontinuity in terms of additional degrees of freedom (DOF) or remeshing. The goal of my research is to develop a novel technique that should run independently of the number of cracks. To that end, we propose a graph-based Finite Element Method (FEM) for remeshing-free fracture simulation [2].

When a fracture occurs, instead of remeshing or introducing extra DOFs in the system matrix, Graph-based FEM reformulates the internal elastic energy of a mesh to simulate the independent movements of disjoint segments produced due to material disintegration. Correspondingly, the system matrix size of graph-based FEM remains constant throughout the simulation making it much faster than state-of-the-art fracture techniques. Thus, on one hand, graph-based FEM adds negligible computational overhead compared to regular FEM and on the other, is capable of rendering fracture for a wide range of materials — brittle & ductile, isotropic & anisotropic.

Using a random graph technique, we further extend graph-based FEM to demonstrate how one can model the effects of material impurity on crack propagation in an object mesh [3]. Our probabilistic damage mechanics can capture the variation in material strength and corresponding fracture pattern inside an object. The method also enables an artist to embed any kind of fracture pattern on a volumetric mesh and direct how an object breaks during simulation.

We have also designed and implemented an interactive, virtual sculpting framework by combining our graph-based FEM with Galerkin multigrid method [5]. Our framework can simulate complex cutting and fracture of high-resolution meshes ($\sim$ 300k tetrahedron elements) at an interactive rate ($\sim$ 30 frames/sec). It also renders faithful haptic feedback and provides multiple tools to perform various mesh manipulation operations e.g., deforming and cutting.

I have multiple interesting directions for future work in my mind, including the exploration of different machine/deep learning-based frameworks to model fracture using graph-based FEM. Research areas at the intersection of computer graphics, applied physics and geometry fascinate and intrigue me and I would love to work on any exciting problem in such domains.

In the course of my PhD, I acquired relevant theoretical knowledge in multiple diverse disciplines to solve the problem at hand. I am comfortable with programming in different languages like C, C++, Python and with various APIs such as OpenGL and CUDA. I also have rudimentary exposure to various rendering software like Houdini and Blender.

I really look forward to an opportunity to work in your research group. I would be more than happy to talk with you further about my research or about any other information that may be needed.

Thank you for your time and consideration.

References

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[5] Zangyueyang Xian, Xin Tong, and Tiantian Liu. A scalable galerkin multigrid method for real-time simulation of deformable objects. *ACM Transactions on Graphics*, 38(6), 2019.