Destruction System

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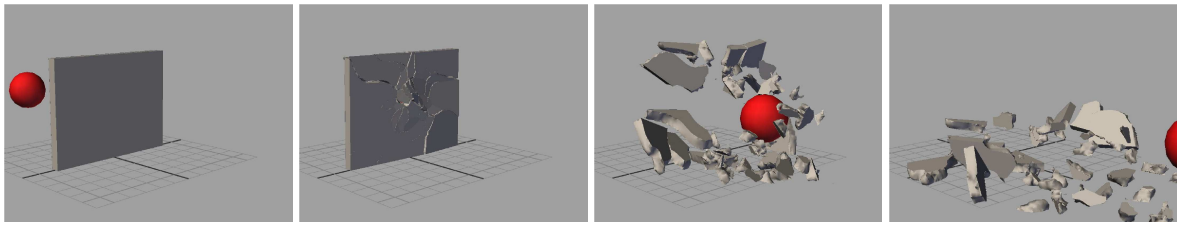

Figure 1: *Our destruction pipeline maintains the original geometry while giving artists control over crack and breaking patterns.*

1 Introduction

Simulation of destruction is becoming increasingly necessary as destroying practical models do not provide the realism needed when dealing with locations that are difficult to reproduce. For the movie *Indiana Jones and the Kingdom of the Crystal Skull*, this motivated Industrial Light & Magic (ILM) to develop a new fully 3D destruction pipeline which gave the artists the ability to take a piece of geometry, destroy it and integrate it seamlessly into the larger simulation framework, Zeno.

We chose to separate our destruction pipeline into two parts. In the first step, the fracturing of the geometry is done as a preprocess. Any object to be destroyed is pre-scored. A primary advantage of this is that it allows the fracture iterations to be decoupled from the subsequent rigid body simulation. The disadvantage is that the artist needs to be able to come up with plausible fracture patterns before simulation. To deal with this we provide real-time crack pattern visualization tools. In the second step we simulate the pre-scored geometry using a modified rigid body engine that supports clustering of geometry. Here we present this pipeline and how it is used.

2 Modeling

The first step is the fracturing of the original geometry. Our method retains the all details of the original geometry on the exterior and automatically transfers any important information such as texture coordinates to the new broken pieces. The interior crack faces of the geometry can have variable roughness as specified by the artist. Since cracks are exact and sharp, our tool also allows for post-process beveling of edges to handle hard edges which may look unrealistic in some situations.

A modeling approach was chosen to allow artists to have creative freedom over the fracture patterns. The tools have varied levels of control. They range from very broad, such as specifying which parts can and cannot break in a binary fashion, to very detailed, such as painting exact crack patterns by hand.

The out put of the pre-scoring step is a set of new geometry along with the supplemental data needed by the simulation step to give the appearance that he fracture is not pre-scored, such as face data and new texture coordinates.

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3 Simulation

Once the geometry has been fractured, the next step of the pipeline is to simulate the geometry as a dynamic object. The pre-scored pieces are grouped together as one piece of geometry known as a cluster. During simulation, the cluster can break automatically upon any impact, only when forces cause sufficient strain between sub-bodies, or at keyframed times. Furthermore, different areas of the clustered geometry can be tagged as "stronger" than others, requiring more force to break. This tagging can be performed manually using spatially varying inputs or automatically, making the inside of an object stronger than the outer edges. In addition to tagging areas of the cluster, artists can also specify a decay rate between pairs of bodies to allow the object to gradually break down.

The information resulting from the actual break simulation, such as times of separation, can be used for adding additional effects like emission (i.e., emitting dust between pieces as they break). Such additional effects can either be done during the initial simulation or as a post process, further streamlining the workflow of the artists.

4 Conclusion

We have presented the method developed for destruction scenes at Industrial Light & Magic. This pipeline has been demonstrated effective through its use in films such as *Indiana Jones and the Kingdom of the Crystal Skull* and *Ironman* and was prototyped on *Transformers*. We plan to continue adding additional controls as new challenges arise.

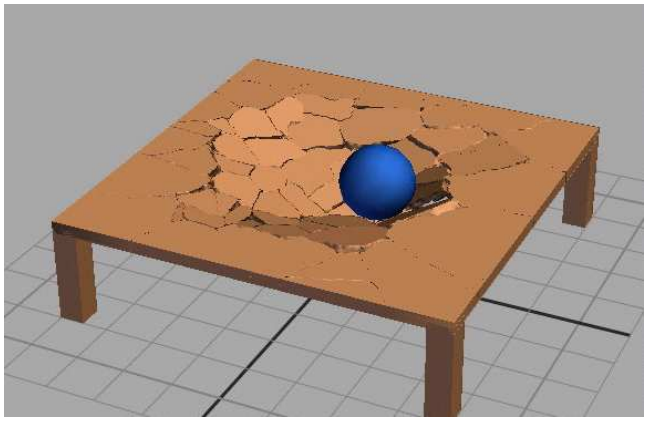

Figure 2: *This table being shattered demonstrates how portions of a pre-scored object can be designated as stronger than others, as was done with the outer edges of the table.*