Transformers 2 : Breaking Buildings

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Figure 1: *Trasformers 2 "Revenge of the Fallen" (c) Industrial Light Magic. All rights reserved.*

1 Introduction

The fragment clustering system was built as a method to control large sets of constrained rigid geometry. Fragment clustering allows artists to initialize sets of geometry as a single rigid body, then dynamically break the objects during the progression of the simulation. This system was originally developed for "Transformers" by Rachel Weinstein Petterson, Brice Criswell, and Abhik Bose Paramanik, and later adapted for use in "Star Trek", "Transformers : Revenge of the Fallen", "The Last Air Bender", and most recently, "Iron Man 2". While earlier uses of the system were limited to artistic animation of the rigid constraints with limited strain evaluation, recent improvements have allowed the artists to gain much greater control over complex destruction scenarios.

2 Simulation

The fragment clustering system is designed to aid the artist in their ability to control the fracture properties of large scale rigid body simulations. Fundamentally, a cluster is a rigid constraint between a set of rigid bodies. The fragment clustering system is an automated method for adjusting the sets of constrained rigid bodies.

At the beginning of the simulation a connection graph is initialized based on the rigid body's nearest neighbors. Each connection between the bodies represents a rigid constraint within the cluster, and is given initial strain values. At the beginning of each of frame, the strains within the connection graph are evaluated by first advancing the clustered objects with all cluster constraints deactivated. The results of this unconstrained advancement is then used to calculate the strains within the cluster. After the strain evaluation is completed, the simulation state is re-set to the beginning of the frame and the connection graph is updated to reflect the new strains. When connections within the graph are removed, due to exceeding strain thresholds, rigid objects may be removed from the cluster and continue to advance normally.

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3 Controls

In order to achieve a realistic breaking pattern it is necessary to vary the internal strain of the connection graph based on the material properties of the cluster. For example, the crumbling nature of the cement in the Paris Tower sequence(see Figure 1) was accomplished through variations of a Voronoi diagram, while simulations of broken glass required the use of image based fracture patterns. To solve the problem of initializing the internal strains based on whatever material the artists could imagine, we relied on our dynamic field system. Along with initialization, the field system was used to control decay rates of the clustered objects during the progression of the simulation. This was useful for objects traveling through mediums of varying densities.

Along with the use of fields to tune the cluster strain parameters, the artists had the option to use non-physically based breaking controls. Options were provided to force a percentage of the connections to break based on a time or event within the scene. We also provided the ability to manually set strain values for subsections of the clusters, and specify spatially based lifespan attributes. Regardless of how the clusters were processed, each breaking method used the internal strains of the connection graph to ensure that the cluster would break apart in a physically realistic manner.

References

GUENDELMAN, E., BRIDSON, R., AND FEDKIW, R. 2003. Nonconvex rigid bodies with stacking. *ACM Trans. Graph. (SIGGRAPH Proc.) 22*, 3, 871–878.