SimpleBullet: Collaborating on a Modular Destruction Toolkit

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Figure 1: Production images: Doctor Strange (©2018 Marvel. All Rights Reserved), Incredibles 2 (@Disney/Pixar) and destruction test (Disney).

ABSTRACT

This talk discusses the SimpleBullet destruction system that was initially developed at Industrial Light and Magic (ILM), and then subsequently adopted and extended by Walt Disney Animation Studios (WDAS) and Pixar Animation Studios (Pixar). SimpleBullet is a set of HDAs and compiled plugins, built on top of SideFX's Bullet DOPs, along with modifications to the open source Bullet rigid body solver. We discuss the toolset as a whole, as well as pipeline integration efforts and extensions made by WDAS and Pixar.

CCS CONCEPTS

$\bullet \ Computing \ methodologies \rightarrow Physical \ simulation;$

KEYWORDS

destruction, houdini, bullet, collaboration

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1 BACKGROUND

ILM's SimpleBullet is a suite of tools and workflows in Houdini [SideFX 2018] for rigging and simulating rigid body dynamics and destruction. It is comprised of a set of HDAs, compiled plugins and modifications to the open source Bullet rigid body solver [Coumans 2018]. Its goal is to allow FX artists to work entirely in SOPs, abstracting the complexity of building custom DOP networks, as well as separating concerns such as rigging, simulation and retargeting/rendering into modular, reusable components. It was originally built over the course of *Spectre*, and was refined and used on *Rogue*

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One: A Star Wars Story, Doctor Strange, Star Wars: The Last Jedi and Ready Player One. Since being adopted by WDAS and Pixar, it has been used on *Ralph Breaks the Internet: Wreck-it Ralph 2* and *Incredibles 2*.

2 OVERVIEW – INDUSTRIAL LIGHT & MAGIC

The core of SimpleBullet is its rigging workflow. A single rigging SOP consumes geometry and provides a high-level interface for the FX artist to group/filter the geometry, perform fracturing, generate low-res convex hulls for simulation, and build and configure constraints. This combination of choice of fracturing, constraint types and break configuration, as well as rules about how to retarget the geometry post-simulation, form a "material." The rigging node has a set of presets that provide common desired material types out-of-the-box, such as concrete, glass, wood and tearable metals. The tools are used to produce both hard/rigid behaviors (like crumbling concrete), as well as soft behaviors (like deforming metal or plastic), all through the use of constraints and custom retargeting post-simulation. The result is a rigged asset that we can then cache to disk and re-use in multiple simulation contexts.

We simplify the geometry that the artists interact with down to a single centroid point representing a body, and line polygons connecting those body points representing constraints between bodies. We provide tools to convert between real geometry and this points-only representation, and back again, as well as a viewport visualizer to display full geometry when working with points. The solver consumes this points data and outputs it, so simulation caches are lightweight. At retarget time post-simulation we convert back into real geometry, for caching to disk. Rigid retargeting can also be done at render time via a Mantra procedural.

A custom Bullet 6-DoF constraint type provides both hard/rigid behaviors as well as soft and spring-like behavior (whilst remaining stable). This is a Bullet constraint that's based on Erin Catto's "soft constraints" [Catto 2011]. This gives intuitive and predictable behavior without cryptic CFM/ERP parameters.

Soft constraints along with timed/delayed re-hardening of constraints are used to emulate tearing metal whilst maintaining quick sim times. Post-simulation geometry retargeting makes use of the constraint network to know which constraints broke and which did

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not in order to seamlessly blend small gaps and normals between adjacent fragments.

The suite of tools includes a method of automatically detecting duplicate geometry, in order to retroactively apply instancing to otherwise non-instanced meshes. This method detects duplicate geometry (accounting for rotations and translations in 3D as well as UV translations) and outputs instanced packed geo. This can significantly reduce the amount of geo that requires processing (fracturing, subdividing, etc); for buildings and other structures that are highly repetitive, it can detect on the order of 90-95% duplication, leaving only 5-10% requiring processing.

3 INTEGRATION APPROACHES

With SimpleBullet having proved itself at ILM, WDAS and Pixar then undertook the challenge of integrating it into their pipelines. Although the three companies use Houdini for FX, the needs of productions, as well as the technologies available for publishing and rendering differed. Adopting another company's tools can often prove difficult for a number of reasons: different libraries, methodologies, renderers and UV systems. Over the course of the integration, the toolset evolved and adapted to each company's needs. SimpleBullet's evolution at the three studios was linked to the needs of each; ILM's effects are live action based and therefore focused on realism and physical forces, WDAS and Pixar often require more stylized effects for feature animation.

4 WDAS INTEGRATION

The necessary nodes to render correctly using Ptex [Brent Burley 2008] and the Hyperion renderer [Christian Eisenacher and Burley 2013] were developed at WDAS. ILM's shattering tools were modified to store pre-shatter attribute values for faceId, uvs and Pref. Meshes are pre-subdivided prior to fracturing, and on-the-fly render subdivision is disabled.

A "Destruction Template" was created to give FX artists easy access to rigs and shattered geometries, along with the ability to reuse rigs and destroyed assets in multiple shots. This was done by adding the ability to extract the building blocks of the setups in containers called buckets (such as rigBucket, simBucket). Using WDAS's *Toolshed* system for sharing Houdini node graphs, each bucket can have a variety of rigs. For example, the rigBucket could be populated with a car rig or the rigged geometry of the car itself, which can then be plugged into the sim and export buckets. Artists can publish their rigs as CPIO files to make them available to other artists, either through buckets (with additional QC checks), or as graphs through Toolshed.

Optimizations were made by making heavy use of instancing, by processing many duplicate objects at once at the object level. Objects can be placed at the origin and shattered with a high density of cuts. Once the geometry is subsequently moved back to its intended world space location, the constraint graph is made unique for each, in order to reduce the likelihood of the duplicate fracturing being too apparent during simulation. Each unique building/geometry is only shattered once, instead of potentially hundreds of times, meaning large amounts of processing time and storage space is saved, as well as rendering time by using WDAS Aurora instancing. For art direction, layout animation of vehicle movement is combined with the simulation using a feedback loop. The target directions for use in the simulation are pre-computed and mixed with the simulation through updates to velocities/forces. A slider between full animation and full simulation allows the user to choose the extent of influence that the animation has on the simulation.

5 PIXAR INTEGRATION

Pixar mostly leaves the choice of tools up to individual artists. For rigid body simulation and destruction work some artists use SimpleBullet on its own, some prefer native DOPs, and others use SimpleBullet only for fracturing and constraint setup. Art-directability is a primary concern at Pixar. Artists are often required to create very specific fracture patterns, which prompted the development of modifications to SimpleBullet to provide the ability to use alternative fracturing tools. The SimpleBullet CSG Voronoi cutting was modified to support a "power diagram" method where Voronoi cells can be weighted.

SimpleBullet has been used at Pixar for rigging cars for crashes. Specialized joints and visualizers for constraint limits were added to SimpleBullet to help with this rigging process. Specifically, hinge constraints with proper orientation and constraint limits to simulate moving parts such as car doors, hoods and trunks. Spring and slide constraints were combined to model the suspension of a car, where slide constraints limited motion in the up-down direction.

Work was also undertaken to integrate SimpleBullet into Pixar's USD-based import/export pipeline. Models have intrinsic primitive attributes (usdprimpath) that are used in pattern-matching filters in SimpleBullet's rigging node. Fox export, tags are added to different kinds of assets to guide the USD export tools. Rigid, deforming, and shattering objects are automatically mapped to the appropriate export settings ("overlay transforms", "overlay points", and "overlay all").

To stay synchronized with ILM and WDAS while making local Pixar-specific modifications, Houdini's VCS-friendly (plain text) HDA feature was used.

6 COLLABORATION PROS & CONS

SimpleBullet OTLs and C++ source files were uploaded and shared between the facilities via *git* every few months. Care was taken when integrating upstream ILM changes into local WDAS/Pixar codebases. With several different departments involved across all three facilities (FX, TD, R&D, Pipeline, etc) many people had to get familiar with the codebase and nodes, so good documentation is required. Due to assets and materials that could not be shared between companies, sometimes reporting bugs and issues proved difficult. Divergence specific to each facility can be hard to maintain, particularly given the nature of Houdini's HDA format.

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