Racing to the Finish Line: Effects Challenges on Cars 3

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ABSTRACT

The world of Disney Pixar's *Cars 3* finds our hero Lightning McQueen on a journey to reconnect to the roots of "real" racing as he struggles to stage a comeback in a sport which is quickly evolving past him. Over the course of the film, our characters race on beaches alongside lapping waves, in abandoned ghost tracks, through winding mountain forests, and even in a raucus, muddy demolition derby. Providing a sense of believable interaction between our characters and these varied environments in over 600 shots was one of the key responsibilities of our FX team on *Cars 3*.

In order to achieve the scope and scale of this work efficiently, we built on sequence-wide workflows and independent "clustered" simulations presented last year in (Reisch et al. 2016), extending these strategies to effects unique to the show. Creating a common shared core to our simulation and effects-asset rigs provided artists with a familiar starting point regardless of whether they were working on volumetric dust, rigid-body debris, point-based dynamics sand, or even viscous mud simulations. A focus on stability, artist experience, and optimized workflows which scaled to take advantage of our render farm, allowed our team to achieve visually consistent, high quality results on an accelerated schedule.

CCS CONCEPTS

•**Computing methodologies** →**Physical simulation;** *Volumetric models;*

KEYWORDS

volumes, fluid dynamics, simulation, rendering, production pipeline

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1 A SHARED STARTING POINT

The foundation for almost all of our effects rigs on the show began with two key components: a consistent way to import and setup our cars to generate forces, collisions, and emission data, and a consistent way to partition our simulations into world-space clusters which could be computed independently on our render farm.

1.1 Car Import and Setup

The Car Import Module was built to feed tire and collider data into several rigs, including the tread marks and dust rigs. It took input animation data from USD and produced optimized elements for visualization and data. These included deforming and static wheels with and without spin, and shrinkwrap wheels and body with fixed topology with and without spin.

1.2 Clustered Simulation

We designed a simulation clustering system in order to improve artist turnaround time and increase our simulation detail in a variety of scenes, some featuring more than 300 characters emitting dust, tire smoke, or interacting with mud. We implemented two techniques for partitioning: path clustering used primarily for cars racing along a track, and a grid clustering scheme for shots with larger crowds. The clustering template was used in almost all of our effects simulation rigs, promoting both a consistent artist experience and consistent visual results. This approach not only enabled parallel execution, but also provided structural granularity, such that individual simulation clusters could be replaced during shot work.

2 LEAVING OUR MARK

Our cars travelled over a variety of surfaces in this film, leaving tread marks in 230 shots. In many instances these merely helped integrate the cars, in others the marks played a storytelling or compositional role.

To handle the volume of shots while allowing for artistic input, we developed a texture projection system that generated tread mark textures in Houdini and drove shaders in RenderMan using Pixar's proprietary Leonardo projection system. The Houdini portion generated ribbons with uv coordinates based on the profile of the tires as they moved, recording slip and spin for each time sample. We used the uv coordinates to tile suitable tire textures along the path, modulating presence, blur and noise with slip and spin.

A second Houdini stage diced the texture in worldspace, throwing away empty clusters and calculated the projection matrices for each cluster. The diced texture and projection were exported to TEX and USD. In Katana/Renderman the signals were read by the ground shaders. In the case of dirt and sand displacement was applied along with albedo shifts. In the case of asphalt, albedo and specular response were modulated.

3 A VOLUME OF VOLUMES

The huge number of shots involving smoke and dust meant we needed an efficient simulation method combined with an optimized standard workflow. We used Houdini's Pyro Solver for artist friendliness. Emission and collision data was pre-cached and encoded with attributes to allow for specific control of the contribution from individual cars and wheels.

Our clustered workflow enabled us to optimize the voxel size relative to camera as well as halting simulation altogether as clusters departed camera view. Per cluster resolution overriding was also provided. Density flow across clusters was unified with the influence of a single ultra fast/low resolution global air simulation.

For closeup shots dust emitted around the wheel needing more detail and accurate collisions, an alternate system was designed to simulated volumes ub car body space. These simulations dissipated quickly as they were fed back into the world space clusters mentioned above.

4 SPLASHING IN THE MUD

The mud pit simulation for the Thunder Hollow Crazy Eight sequence required stability, fast turnaround times, and controllability. With over 50 mud shots in the sequence it was important that each step in the process was efficient to meet production deadlines while allowing for artistic controls to address director notes.

4.1 Mud Dynamics

For our mud dynamics it was necessary to define a initial detailed starting point that seamlessly transitioned into a convincing splashing mud simulation. This simulation needed to interact with characters and leave chunky details in their wake.

For this we used a modified flip simulation in Houdini with per-point viscosity and density attributes. These attributes would begin in a high viscosity state to preserve initial details. As cars interact with the particles they transition to a free-flowing, reduced viscosity state to allow for splashing details. Over time the active particles decay back to the high viscosity state to preserve tire tracks and additional piling as splashes stack over time. We add chunkiness and variation to our simulation by partitioning the mud particles into voronoi regions and randomizing our attributes by cell id. This allows for nearby particles within the cell to behave with a similar viscosity but neighboring cells to flow differently due to their viscosity difference.

4.2 Base Simulation

To get approval on the general shape of the simulation we iterate on a single lower resolution base simulation. The starting point of this sim begins from one of several pre-roll patterns created by animating simple tire colliders through our mud and then locking our particles down after the mud dynamics runs it's course.

We purposely constrain the dynamics to avoid excessive splashing and to help preserve tire tracks. This simulation typically contained 50 million particles and is run as a single simulation.

4.3 Clustered Splash Simulations

Once the base simulation is bought off on we re-introduce higher resolution splash detail by partitioning our base simulation into clusters that simulate independently. These simulations use the base sim as a collider and for birthing particles into the higher resolution partitions.

We reduce the viscosity to allow for smaller scale watery characteristics that are typical in splashing mud.

4.4 Meshing

Meshing our mud simulations proved to be one of the more difficult challenges. The mud mesh is unforgiving to popping artifacts as noticable small scale features must persist over time. To reduce artifacts we split our particles into slow and fast moving groups. These groups were then converted to signed distance fields with different settings and smoothing.

For slow moving particles we sacrifice detail for stability by increasing smoothing and increasing particle influence. For fast moving particles that are more dynamic and difficult to track we have smaller particle radii and minimal smoothing to preserve the higher frequency detail.

4.5 Rendering

For rendering we combine our slow and fast moving signed distance fields and create a single processed mesh. At this time we transfer attributes derived from the particles to add detail during the rendering phase. These attributes include an advected space for stretchy/compressed displacement features, viscosity cell id to allow variation in color, and hardening state to allow for regions to render more like dirty water vs thick clumpy mud. As a final detail we introduce advected persistant particles that we attach instanced geometry for additional clumps withing the mud.

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