Dust and Cobwebs for Toy Story 4

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Figure 1: Antiques Store location from Pixar's *Toy Story 4* ©Disney/Pixar.

ABSTRACT

The Toy Story universe makes its home at small scales, with the camera sometimes just a few centimeters from surfaces where typical shader approaches are unable to provide the desired level of detail. For environments like the Second Chance Antiques Store for Toy Story 4, the Set Extensions team developed systems to generate dimensional, granular elements such as dust, small debris, and cobwebs to enhance storytelling and ambiance. In addition to improving realism, these elements help indicate how hidden or exposed an area is from human observation and elevated the sense of drama and history.

CCS CONCEPTS

• **Computing methodologies → Animation**.

KEYWORDS

dust, cobwebs, simulation, rendering, optimization

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1 DUST

1.1 Prototype

Early on in production, a development shot was created where three FX Artists worked for two weeks to explore the look and a variety of techniques. This test revealed several challenges. Environment geometry was complex, with additional complexity anticipated in real production. A large number of curves was required to achieve the desired look. Scalability and optimization became immediately important, and leveraging automation and proceduralism in our authoring workflows would be crucial for our two Set Extensions Artists to execute over 300 shots.

1.2 Dust Generation

The dust generation algorithm consisted of two phases: collection and advection.

First, in places with normal air circulation and devoid of human activity, dust collects on open, exposed surfaces and is less present on covered areas blocked by nearby objects. This initial phase involved filling empty three dimensional space with points and settling them to nearby surfaces by shooting downward facing, jittered rays.

Second, human activity such as footsteps and cleaning routines was observed grooming dust distribution. This behavior cleans up exposed areas and leaves dust concentrated in corners and higher surfaces where humans tend not to reach, such as the tops of tall furniture. Various methods for simulating human activity were tried, including projecting cleaning rays from a volume reflecting human height. Eventually a simple ambient occlusion algorithm with a search radius similar to the length of a human arm proved to have the best results.

This dust signal generation was engineered to be applicable either to a single asset, a composed environment, a sequence, or individual shots. Each one of these methods was useful and allowed artists to be strategic in authoring and deployment.

1.3 Optimization

In reality, dust is fairly straightforward– lots of short, tiny fibers. As is common in computer graphics, much of the work became searching for the optimal level of realism within the boundaries of available resources. In a dusty area like the Toy Story 4 Antiques Store, the number of curves required to achieve the ground truth is simply too large to replicate digitally, so the goal instead was to create the maximum possible detail that system resources and the renderer could handle using a cocktail of optimization tactics.

Generating the dust signal proved to be computationally intensive, so several approaches to balancing the work were used. In each shot, the area relevant to the animated camera frustum was broken into spatial buckets (ranging from 5 to 40 buckets per shot depending on camera coverage) and sent to the farm in parallel to identify dust distribution. Each bucket generated 1,000,000 to 15,000,000 dust points in a 100x100x800 centimeter area. Frame caches were then generated with the combined bucket data and more accurate frustum, object occlusion, and distance culling were applied to further minimize the amount of data required to load per frame by the renderer. An in-house Houdini Engine Renderman procedural was additionally utilized to generate render-time curve geometry from the cached seed point data, shipping to the renderer only the bare minimum of attributes– id and density values.

The decision to cache the data per frame was a trade-off between disk space and render-time memory consumption. Since visual quality was closely related to the number of curves, enabling the renderer to handle as much data as possible for each frame was prioritized over the cost of redundant data. The data size was large (50-300 Mb per frame x 25294 frames) but was predictable even with cameras traveling long distances. also minimized.

1.4 Debris

Debris such as dust bunnies, hair, and grains were generated in Houdini with a variety of simulations and simply scattered in most scenes. Certain heuristics such as increased accumulation on rugs or adjustment for storytelling and the particular characteristics of an object further informed distribution.

2 COBWEBS

Cobwebs elevate the storytelling throughout the film, heightening the sense of danger or suspense. Unlike spider webs that have spiral shapes, cobwebs consist of very irregular organic formations that conform to the environment tightly. A simulator was developed to imitate a spider's behavior and build these complex structures.

2.1 Cobweb Simulation

A user roughly designated the area for a cobweb by scattering points on nearby surfaces and casting random rays to adjacent surfaces to create initial lines. Spider points were then scattered on the lines and the simulation started. In each simulation step, each spider picked a random point in space within a ranged jump distance, searching for the nearest existing line. The target line was then split into two with a new line added, resulting in all three meeting at a central new spider position. If a blocking surface was found between the starting point and destination, the spider instead landed on the detected surface.

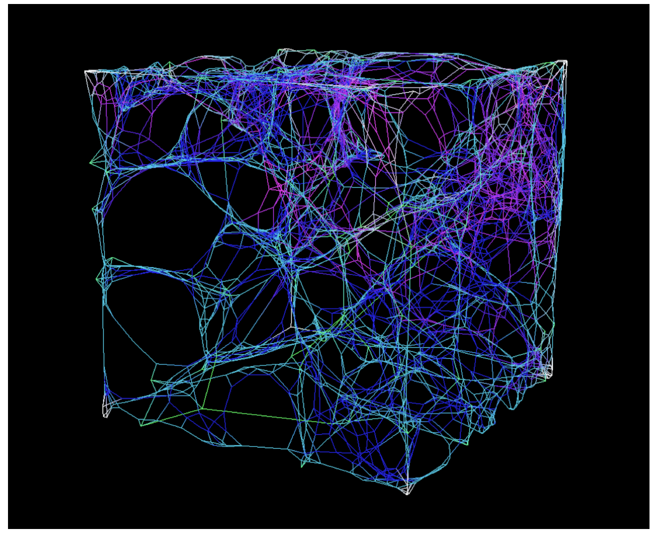

Figure 2: Cobweb Simulation ©Disney/Pixar.

Tension between the lines was achieved by applying a simple smoothing filter as a post process, which while not physically correct still produced a visually plausible result and was cheap to execute. In most cases five to ten spiders and 50 to 1000 simulation steps were used to build each localized structure. For a few large and sparse web structures, a Bullet constraint simulation was applied to create a sagging shape.

3 CONCLUSION

Evolution of these workflows and pipeline was an emergent process, where flexibility and aesthetic were prioritized. The dust, debris, and cobwebs were originally intended only for a few contained areas, but as the Art and Lighting departments saw visual results mature, appetite for these elements grew to include every sequence in the Antiques Store and a handful elsewhere.

For Toy Story 4, this extra realism not only helps enhance storytelling and allude to the history of environments, but also conveys the small scale of the toy world. Viewers naturally perceive information about environments through small details, and in computer graphics the uncanny absence of these elements has become more noticeable as modern renderers achieve increasing fidelity throughout the frame. With advancements in techniques, automation, and proceduralism, the capability to produce these fine details will match the anticipated growing demand.

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