Fine Tuning Every Grain on the Beach

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For the interactive beaches featured on Pixar's Elio, we developed an innovative method which improved upon past approaches. Traditional interactive sand pipelines are made of three parts: a render-optimized surface with limited grain interaction for most of the set, a limited number of interactive particles, and a compositing integration step to bridge a notorious gap between static set sand and interactive sand. Our approach introduces a render-optimized sand asset entirely made of points with reading and writing capability for every point, ready to modify for interaction without look alteration. This drastic workflow simplification provided a much more capable pipeline leading to the efficient authoring of individually tweakable sand grains above half a billion. By leveraging a perceptual model that uses the camera frustums of all frames, we plausibly represented expansive areas which in reality would be composed of many trillions of grains.

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1 OVERVIEW

The sand pipeline of Pixar's Elio was aimed to reduce inter-dependency between production departments working under extremely tight deadlines. The opinion of each department propagated, in the smoothest possible way, to downstream

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departments, easily accommodating varying departmental needs and workflows. Our pipeline and this talk are organized around the three main topics described below.

Sand Asset. The Sets Department defined the initial beach topology using a shaded subdivision mesh (Fig. A). This ground geometry, with shader-based displacement (Fig. B), was shared with Animation and Cloth Simulation Artists as a reference for character-ground contact. For other departments, the ground geometry and displacement were converted into sand grains at render time via a Houdini procedural. To optimize cpu and memory performance, grains were distributed using a perceptual probability function based on camera proximity, depth of field, and motion blur (Fig. C). The Houdini procedural also generated temporary pre-viz sand interactions from animated characters using an automatic, low-cost kinematic system. The points were converted to a grain model (Fig. D). For shot work, the Effects Artists wrote static and dynamic grains to disk, replacing temporary pre-viz interactions with accurate boundary simulations. From this stage forward, the Houdini procedural was disabled, and the points were rendered from disk (Fig. E).

Grain Model. Originally modeled as subdivision surface, each grain prototype was converted to spatially oriented spheres using the neat coincidence between the medial axis and the numerical singularity of the signed distance function. This conversion also included a shading space, mapping equally the subdivision surface and the spheres, so that paint and shading signals were used to initialize the grain simulation in a manner whereby the signals were preserved. In addition to horizontal texture variation, shallow grains of sand were shaded with a lighter color to represent a drier and exposed sand, whereas deep grains of sand were shaded with a darker color to represent heavier minerals and higher water content. Because the size of the grains could vary widely in world space, it was common for distant grains to be very large. To accommodate for such large grains, the grain material was configured so that the top of a large grain would be shaded like a small shallow grain and the bottom would be shaded like a small deep grain. For extreme close ups, the grain model could be morphed to a higher level of detail.

Interaction. Every grain had read/write authoring access and was available for simulation, for reading or writing the nearby information, or for duplication. Our holistic grain system used a single geometric representation method so that there was no need for surface/point compositing integration. The simulated grain could be rendered directly into images without seams. The asset was multi-thread friendly for large areas and detailed enough for extreme close-ups. For character-to-sand interactions, artists developed grain manipulation tools including:

- Procedural kinematic manipulation. We found that including displacement based on the Decay of Turbulence observed by Kolmogorov [Kim et al. 2008] was an important part of efficiently producing chaotic sand patterns.
- Physically based methods using Houdini: Vellum, rigid body, dynamic particles and kinematic Particles.
- Image based manipulation using projections of one or more images obtained from photographic reference of beaches, to modulate grain position or color.
- Neural network approach to compute an initial resting position for grain packing.

2 CONCLUSION

Our talk includes technical information for setting up a similar pipeline, as well as Artist stories covering the necessary extensions discovered during production to achieve the artistic vision of the Directors. The result is a very capable sand pipeline that can accommodate for a wide range of situations, and even accommodate for late Sets Dressing notes.

REFERENCES

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