CrackTastic
Fast 3D Fragmentation in "The Mummy: Tomb Of The Dragon Emperor"*

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Abstract: We have developed an efficient technique for fast and production-friendly fragmentation of solid (*i.e.* closed) geometry. It is based on novel data structures and algorithms that allow us to employ fast and robust level set operations to generate fragments at very high resolutions and speeds far exceeding fully physics-based simulation techniques. Our tool, dubbed "CrackTastic", is embedded into a larger Houdini framework that adds artistic control to the fracture generation as well as augments with physics-based animations by means of rigid body dynamics (RBD) of the fragments. "CrackTastic" is derived from a vision to balance fully physics-based fracture simulations and completely manual modeling since both extremes pose major disadvantages in terms of production time and artistic flexibility. In contrast, our new framework allows a single artist to produce massive fragmentations on the order of minutes as oppose to hours or even days. "CrackTastic" has already been used in the newly released movie "The Golden Compass", but more significantly constitutes a key-technology in the upcoming movie "The Mummy, Tomb Of The Dragon Emperor" that features complex fragmentation on a very large scale.

Overview: The input to "CrackTastic" is a "base-geometry" (*e.g.* textured polygonal mesh) with associated (arbitrary) impact points and the output is an animation of the fracturing. The first step in our pipeline converts the base-geometry to a level set using a new robust scan-converter that can handle self-intersecting meshes. We then have to option to produce shells (*i.e.* double-walls) from the solid base-geometry. This is a highly desired feature for "Mummy 3" and is easily accomplished by means of fast level set operations. Next, the impact points are used to generate so-called "scatter-points". The position (and other attributes) of these scatter-points are computed by means of simplified physical heuristics derived from the base-geometry and the impact points. We have then developed an efficient level set procedure to recursively generate naturally looking fragments. The characteristics of the fragments (size, shape, density etc.) are easy to controlled or optionally automate. As the final step, RBD is applied to the fragments to account for the dynamics of the shattering. Overall this approach is very production-friendly since it is both intuitive and easily allows for artistic control. However, to facilitate fast level set operations that produce tightly fitted fragments with arbitrarily complex topology, high resolution and no self-intersections, we need some "extra sauce":

DB-Grid forms the fundamental representation of all our geometry processing, and is best described as a highly efficient data structure for arbitrary volumetric data. It employs different blocking techniques to reduce memory footprints and ensure fast data access. It shares several of the benefits of the extremely compact DT-Grid[Nielsen and Museth 2006], but complements with several important improvements. Whereas DT-Grid is strictly limited to (closed) level sets, DB-Grid can literally encode any volumetric data, including of course unclosed (*i.e.* none-manifold) surfaces or even random densities! Furthermore, DB-Grid allows for *both* "random read and push/pop" in *constant time* unlike the logarithmic random read of DT-Grid and complete absence of random push/pop. Thus, we can represent surfaces with DB-Grids of effective grid resolutions exceeding 8000^3, which is more then adequate for VFX production. We currently employ DB-Grid to represent high resolution level sets in "CrackTastic", but we have also used it to dramatically improve the performance of "Blobtacular" presented last year[Museth et al. 2007]. In the near future we also plan to use DB-Grid in Digital Domain's award-winning fluid solver (FSIM) and volume renderer (STORM) to allow for much high resolutions and fidelity. Preliminary results with FSIM look very promising.

Post-processing: Ironically DB-Grid introduces a new problem for in the overall pipeline; the access to very high resolutions level sets obviously result in the generation of meshes with very high polygon counts. To solve this problem we have also developed a fast mesh decimator. Additionally we have extended "CrackTastic" to correctly transfers mesh attributes (*i.e.* texture coordinates) from the "base-geometry" to the decimated meshes of the final fragments. A combination of all these tools and techniques make up the "CrackTastic" pipeline which is routinely used by artists to fracture thousands of terracotta warriors in the upcoming "The Mummy: Tomb Of The Dragon Emperor". We look forward to presenting some of these dramatic shots after the movie release in June.

*Some of the materials included in this submission are place-holders for "Mummy 3" shots that we cannot publish before the movie-release in June.

References

MUSETH, K., CLIVE, M., AND ZAFAR, N. B. 2007. Blobtacular: Surfacing particle systems in "pirates of the caribbean 3". In *ACM SIGGRAPH Sketches*.

NIELSEN, M. B., AND MUSETH, K. 2006. Dynamic Tubular Grid: An efficient data structure and algorithms for high resolution level sets. *Journal of Scientific Computing 26*, 3, 261–299.