An Efficient Level Set Toolkit for Visual Effects

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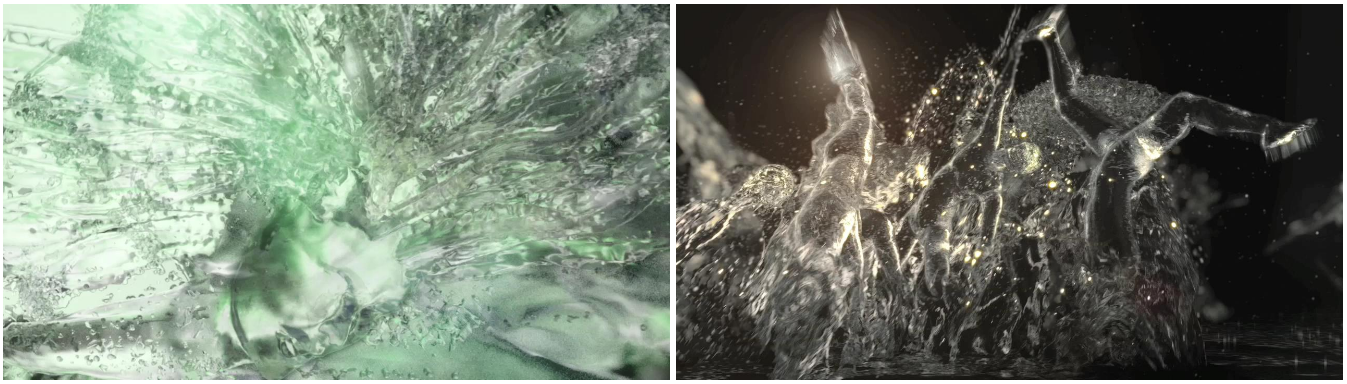

Figure 1: Examples of past production at Digital Domain that made extensive use of our LSTK based on efficient data structures. Specifically, these shots are from a Bacardi commercial where live dance performers are converted to animated level sets with fluid sources on their skin.

Introduction

Over the past couple of years we have developed various tools for visual effects in movie production based on level sets. While most VFX studios, and even some commercial software packages, have had level sets tools for several years we are, to the best of our knowledge, among the first to employ highly optimized data structures. These compact and very fast volumetric data structures allow us to work at unprecedented grid resolutions, which in turn opens the door to new applications. The last two years we have demonstrated this with level set tools specifically developed for fluid surfacing in "Pirates of the Caribbean: At World's End" [Museth et al. 2007] and fragmentation in "The Mummy: Tomb Of The Dragon Emperor" [Museth and Clive 2008]. However, none of these past presentations actually discussed the details of the novel data structure, DB-Grid, which forms the very backbone of our level set implementations. The same was true for many of our fundamental level set tools, like the fast and robust scan-converter of self-intersecting polygonal meshes. These are exactly the topics of the current presentation. We will also show how these tools are tightly integrated with Houdini.

The Data Structure

We have developed efficient data structures and algorithms for storage and manipulation of general volumetric data sampled on a spatially uniform 3D grid. Specifically, our data structure is based on a Dynamic Blocked Grid (hence the acronym DB-Grid) that exploits the *spatial coherency* of uniform grids to effectively and separately encode data values (*e.g.* signed distances) and topology (*i.e.* coordinates). These techniques allow for fast (*i.e.* constant time) data access into 3D grids of very high resolutions (exceeding 10000^3). In addition, our data structure is very general and can be applied to any spatially uniform 3D data regardless of topology and access patterns. In contrast, previous sparse level set data structures, like the very compact DT-Grid[Nielsen and Museth 2006] or the more versatile HRLE[Houston et al. 2006], assume fixed data topology (*i.e.* closed or at least connected surfaces), and require specific access patterns (*i.e.* memory-sequential) for fast data accesst. While DB-Grid is very flexible and general purpose, this talk will only focus on it's applications to level sets. However, we stress that our data structure can be applied to virtually any problem that employs sparse uniform 3D grids, like for instance fluid animations or volume rendering.

The Level Set Tools

DB-Grid forms the fundamental representation for all our geometry processing in the LSTK. This toolkit consists of many different operations and algorithms that can be combined in numerous ways through their common data structure. DB-Grid offers some highly efficient implementations of level set operations like advection/propagation, re-normalization, narrow-band rebuilding, boolean operations, morphological operations, adaptive meshing, morphing, collision detection, mesh-to-level-set conversion and many more. We plan to discuss the details of these efficient implementations and showcase applications from actual production. For instance, our converter which allowed artists to convert self-intersecting meshes of motion captured dancers to level sets in near real-time (see figure 1).

Integration with Houdini

To best deploy the LSTK to artists and technical directors, it needs to be integrated into a familiar 3rd party package. In our case, we chose Houdini because of its flexible SDK (HDK) and general popularity at Digital Domain. It should be noted that Houdini already has support for level sets, but its implementation is based on dense 3D grids which suffer from large memory footprints (or low resolution) and relatively poor computational complexity. However, using HDK we were able to tightly integrate our LSTK based on DB-Grid. This effectively allows us to take advantage of Houdini's existing modeling and animation tools as well as maintain an artist-friendly working environment.

References

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