Levelsets in Production: *Spider-Man 3*

Chris llen   Jonathan M. Cohen   Doug Bloom   Daniel P. Ferreira   Sho Hasegawa   Cory McMahon
Sony Pictures Imageworks

1 Introduction

evelsets are a flexible implicit surface representation that have many applications in production. A levelset represents a surface as a signed distance function (SDF) on a regularly sampled grid. For *Spider-Man 3*, we created a toolset called Sandstorm which included a rich set of levelset-based modeling and animation tools. This included methods for converting geometry into SDF fields and vice versa, methods for transferring surface attributes into these fields, tools for looking up values in an SDF, and many other flexible surface editing operators.

2 Collision Handling

Figure 1: ©Columbia Pictures Industries, Inc. ll rights reserved.

One application of levelset is for particle-object collisions. Typical collision detection and handling methods suffer from either low accuracy, low speed, or many missed collisions for fast moving particles. Our levelset-based collision handler was implemented as a standard Houdini POP, and was used in almost every sand FX shot.

First, we sample the SDF value at the particle position. If the value is positive, it means that the particle is inside the object, so we proceed to collision response calculation. If the particle speed is too high or the object too thin, the particle could go through the object, so more substeps would be required to be able to get a positive levelset value when sampling. However, the speed of SDF lookups means that higher numbers of subsamples are cheap in terms of calculation time.

Once we know that a particle is inside the object, we can calculate the collision normal using the gradient of the levelset. Furthermore, we can encode the object's motion in a velocity field, which allows us to efficiently inherit the object's motion. In cases that we require particles never to penetrate the collision surface, we can also snap their positions to the closest point on the surface using a gradient ascent on the SDF field. We use an impulse method to modify the particle's velocity at the next frame based on the collision response taking into account friction and elasticity.

3 Surface Erosion

Because they are an implicit representation, levelsets allows us to simulate complex surface erosion patterns without worrying about maintaining uniform surface triangulation. By simply subtracting a spatially-varying value from the levelset, we can control erosion

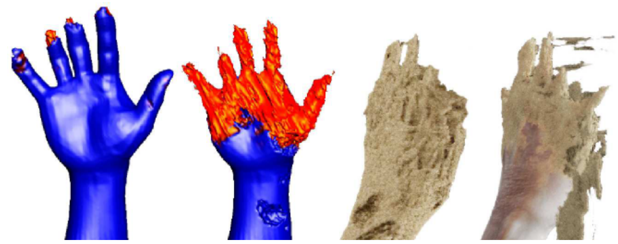

Figure 2: ©2007 Sony Pictures Imageworks Inc. ll rights reserved.

patterns in complex ways. We used magnets and particle systems to control these erosion values based on painted or animated surface attributes.

To animate a hand eroding away as Sandman is vaporized, we first scattered particles over the surface of the hand. We then eroded away a levelset representation of the hand, and released particles when their levelset values fell below zero. In order to obtain a more detailed and organic look, we added layers of spatial noise to the erosion field.

4 Geometry Blending

In several scenes, Sandman forms out of a pile of sand. evelsets provide a straightforward and computationally cheap way of blending and separating surfaces in organic ways. To blend two surfaces, we first create two identical voxel grids large enough to hold both pieces of geometry, and then convert the geometries into levelsets over each voxel grid. A union can be calculated by calculating the point-wise maximum of the two levelsets, $C = max(\ , B$. However, in order to obtain a more organic look, we detect the places where the two objects intersect in the field with a certain threshold and add to the field a magnitude attribute based on it.

$$m = \frac{clamp\,(|\alpha - \quad |, 0, \alpha}{\alpha} \quad \frac{clamp\,(|\alpha - B|, 0, \alpha}{\alpha}$$

where   is the SDF of the first geometry, B is the SDF of the second geometry and α is the filleting distance. Then we calculate the blended levelset with the formula:

$$C = max(\ , B \ + m \ \gamma$$

where β is the blending curve exponential and γ is the size of the extrusion in the blending area. The geometry produced by this resultant levelset will have a smooth blending area, as seen in the figure below.

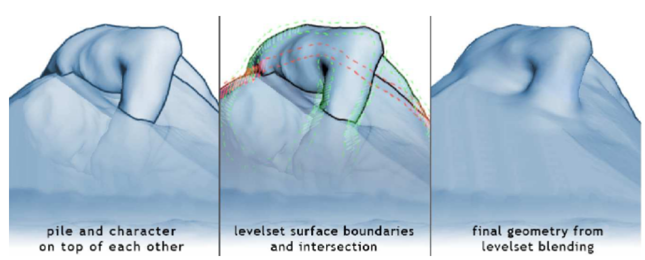

Figure 3: ©2007 Sony Pictures Imageworks Inc. ll rights reserved.

e-mail: dferreira@imageworks. om