Curvature Dependent Polygonization of Implicit Surfaces

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Abstract

We present an algorithm for polygonizing closed implicit surfaces, which produces meshes adapted to the local curvature of the surface. Our method is similar to, but NOT based on, Marching Triangles, in that we start from a point on the surface and develop a mesh from that point using a surface-tracking approach. In a marked departure from previous approaches, our meshes approximate the surface through heuristics relying on curvature. Furthermore, our method works completely on-the-fly, resolving cracks as it proceeds, without the need for any post-remeshing step to correct failures. We have tested the algorithm with three different representations of implicit surfaces, Variational, analytical and MPU, using non-trivial data sets, yielding results that illustrate the flexibility and scalability of our technique. Performance comparisons with variants of Marching Cubes show that our approach is capable of good accuracy and meshing quality without sacrificing computing resources.

1. Introduction

Polygonization of implicitly defined surfaces has been the subject of considerable work in the past years. This is because such surfaces are instrumental in representing smooth objects in a number of fields ranging from animation and computer aided design to medical imaging. Constructing a visual representation of the surface involves obtaining the set of points that satisfy the equation \( f(x, y, z) = 0 \) either by ray-tracing, or by polygonizing the surface. While the most common polygonization approaches are based on volumetric space decomposition, recent work has focused on surface-based methods that can often both provide better meshing approximations to the intended surface at a lower computational cost and do so efficiently, i.e. with a minimum of triangles.

2. Previous Work

Since their introduction, implicit surfaces provide a solution of choice for imaging medical information or point sets arising from digitizing complex models thanks to their flexibility in manipulating data. However, precise and fast visualization of implicit surfaces is difficult. Since the more obvious approaches based on ray-tracing [9, 7, 25, 14] are computationally too expensive for interactive applications even using solutions for speeding intersection calculations such as Kalra [15]. Therefore, subsequent research has focused on approximating surfaces using polygon meshes, more suitable for real-time visualization using commodity hardware. Moreover, polygonal meshes enable us to explore trade-offs between fidelity of representation and interactive performance. In what follows, we will survey the main approaches to surface visualization.

Cell partitioning techniques are the most popular methods for rendering implicit surfaces, by creating a polygonal mesh that fits the surface. The main implementation of this method is the Marching Cubes (MC) algorithm [18] and its variant Marching Tetrahedra (MT) [6] that made it viable to use implicit surfaces for representing model data. MC and its many variants, based on space subdivision provide a simple and effective approach made popular by the availability of source code. However, the resulting meshes are not homogeneous and they exhibit poor quality.

Surface tracking denotes a family of polygoniza-