Processing Irregular Meshes

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Abstract

Most meshes are usually produced with both topological and geometrical irregularity (arbitrary valence, non-uniform sampling). This has been seen as a flaw hindering subsequent mesh processing, because most of the other signals we manipulate everyday (sound, image, video) are acquired and processed as regularly sampled data. Three-dimensional (3D) signals, be they surfaces or volumes, are however drastically and inherently different. Although the main body of work on mesh processing has focused on semi-regular meshes (on which the usual DSP tools can be extended quite nicely), we have focused on fully irregular meshes. Understanding this problem of irregularity, inherent to 3D sampling, is fundamental in widely different applications ranging from mesh modeling to smoothing, parameterization, remeshing, and to even compression or animation. In this talk, we will show some of our latest results (both theoretical and practical) and will also point to the remaining challenges.

Extended Abstract:

The digital media revolution has encompassed three types of data so far: sound, image, and video. Nowadays, these are at the base of many applications in science, engineering, entertainment and many aspects of our daily life (cell phones, cameras, DVDs, CDs, etc). We are presently witnessing the beginnings of a fourth wave with **three-dimensional geometry** emerging as a new, ubiquitous type of digital media data.

Each one of the prior waves coincided with increases in our ability to acquire, store, process and transmit the given data type. These increases required cheap access to necessary computing resources, appropriate digitization technology, and theoretical and algorithmic foundations for the necessary tools. The first two of these prerequisites are largely in place for 3D geometry, with recent progress in graphics cards. Geometry acquisition technology is also maturing: there are now many sources of digital geometry such as 3D laser scanning, MRI, CAT and scientific and engineering simulations, providing models of sometimes over 100 millions samples.

What is missing is a consistent, well-developed theoretical and algorithmic foundation to realize the promise of 3D geometry as a widely used digital media data type. Unlike previous types of data, one cannot readily apply existing theoretical and algorithmic tools developed for previous generations of digital media. Geometric data has intrinsic properties, such as topology, curvature, and non-uniform sampling that render many traditional tools inadequate. This distinction is of a fundamental nature and cannot be overcome by simple adaptation of existing machinery.

Digital Signal Processing [10] has been extremely successful at analyzing and processing regularly sampled data. Most of these tools and mathematical machinery do not readily carry over to the 3D geometry setting, simply because a geometry cannot in general be sampled regularly. For semi-regular meshes, though, most of the DSP tools can be extended quite nicely. However, understanding this problem of irregularity, inherent to 3D sampling, is fundamental in widely different applications ranging from modeling to parameterization, remeshing, smoothing, and to even compression or animation of meshes. This has been the core of our research effort in the last two years, in an effort to build a whole *processing pipeline* for meshes. In this talk we will present our most recent (sometimes unpublished) research results, including:

- **Topology filtering:** to suppress any spurious genus (due to small geometric errors in the acquisition) in large meshes [12,13];
- **Parameterization:** to provide smooth and fast parameterization even for highly irregular meshes, with or without boundary constraints [5];
- **Remeshing:** to provide arbitrary and interactive re-meshing (re-sampling on the 3D geometry) with a

high level of control over the sampling quality of the output mesh [3];

- **Smoothing:** to remove undesirable noise often present on digitized geometry without significant shape distortion [6,7,9,10];
- **Compression:** to encode meshes (geometry and connectivity) by considerably reducing their bit size [1,2,8];
- **Animation:** to animate geometry for real-time applications such as virtual surgery [4].

Although initially inspired by and designed for Computer Graphics, it seems that our research has shown very interesting connections and/or similarities with various other fields such as physical sciences, mathematics, or engineering. Therefore, in addition to the future work in graphics that we have planned (to provide further tools and foundations for geometry processing), we will also focus on the theoretical and computational aspects since geometry is evidently central in many fields.

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