ERCIM “Alain Bensoussan” Fellowship Scientific Report

Fellow: Gael Guennebaud
Visited Location : CGL – ETH of Zurich – Switzerland
Duration of Visit: 9 months, 1.03.2007 – 30.11.2007

I - Scientific activity

In recent years, point primitives have received a growing attention in computer graphics. The fundamental feature of point based geometries is the lack of connectivity such that no topological consistency has to be satisfied through geometry manipulations. Moreover, point-based approaches can directly handle raw data obtained from range scanners or any other acquisition devices which become more and more common.

During the first part of my fellowship, my general goal was to revisit the point-based graphics pipeline from the surface representation and rendering perspectives. More specifically, I focused on the definition of a new point-based surface representation and algorithms targeting robustness, flexibility and efficiency. I first introduced Algebraic Point Set Surfaces (APSS) which aims to define a smooth surface from a set of unstructured, and possibly noisy, points using Moving Least Squares approximation of the data. Compared to traditional polynomial approximations, the key novelty of APSS is to define the surface by directly fitting higher order surfaces like algebraic spheres. It turns out that this approach significantly improves the robustness against low sampling density and reduces the approximation error of planar approaches while retaining high performance. This framework also includes a robust normal estimation procedure.

Next, I extended PSS to support sharp features such as sharp edges, corners, boundaries and peaks. The key idea of my approach is the use of tagged point clouds allowing us to separate the point cloud into different components which are combined using local boolean rules. This simple strategy offer a high degree of flexibility since it is suitable for manual editing by mean of a painting tool, while a tagged point cloud can automatically be generated through some statistical analysis. All these results have been published in [1].

Efficient high quality rendering of point set surfaces is a non-trivial task. In order to make rendering efficient for dynamically changing point sets, I designed a fast sampling and rendering algorithm based on forward warping. The principle of the algorithm is to upsample the point cloud in a view dependent fashion and to render it using a splatting algorithm. A key feature of my algorithm is an adaptive upsampling scheme based on a new view dependent geometric error. In order to keep both the memory consumption and the number of generated splats at each frame as low as possible, I designed my algorithm to operate at the primitive level. Furthermore, temporal coherence is accounted for by a low level cache mechanism. The inherent parallelism of my algorithm makes implementations on massive multi-core processors, such as GPUs, very efficient. As a results, my rendering system is able to handle dynamic point clouds of up to 100k points in real time while in the cases of local changes only it can even handle a few millions of samples without the need of caches or additional high level data structures. This work has been published in [2].

II- Publication(s) during your fellowship

[1] Gaël Guennebaud, Markus Gross. **Algebraic Point Set Surfaces.** Proceedings of ACM SIGGRAPH (San Diego, USA, August 5-9, 2007), ACM Transactions on Graphics, vol. 26, no. 3, pp. 23.1-23.9

Abstract: In this paper we present a new Point Set Surface (PSS) definition based on moving least squares (MLS) fitting of algebraic spheres. Our surface representation can be expressed by either a projection procedure or in implicit form. The central advantages of our approach compared to existing planar MLS include significantly improved stability of the projection under low sampling rates and in the presence of high curvature. The method can approximate or interpolate the input point set and naturally handles planar point clouds. In addition, our approach provides a reliable estimate of the mean curvature of the surface at no additional cost and allows for the robust handling of sharp features and boundaries. It processes a simple point set as input, but can also take significant advantage of surface normals to improve robustness, quality and performance. We also present an novel normal estimation procedure which exploits the properties of the spherical fit for both direction estimation and orientation propagation. Very efficient computational procedures enable us to compute the algebraic sphere fitting with up to 40 million points per second on latest generation GPUs.

[2] G. Guennebaud, M. Germann, M. Gross. **Dynamic Sampling and Rendering of Algebraic Point Set Surfaces.** Proceedings of Eurographics (Crete, Greece, April 14-18, 2008), Computer Graphics Forum, vol. 27, no. 2, pp. 653-662

Abstract: Algebraic Point Set Surfaces (APSS) define a surface from a set of points using local moving least-squares (MLS) fitting of algebraic spheres. In this paper we first revisit the spherical fitting problem and provide a new, more generic solution that includes intuitive parameters for curvature control of the fitted spheres. As a second contribution we present a novel real-time rendering system of such surfaces using a dynamic up-sampling strategy combined with a conventional splatting algorithm for high quality rendering. Our approach also includes a new view dependent geometric error tailored to efficient and adaptive up-sampling of the surface. One of the key features of our system is its high degree of flexibility that enables us to achieve high performance even for highly dynamic data or complex models by exploiting temporal coherence at the primitive level. We also address the issue of efficient neighbor queries and discuss several spatial search data structures with respect to construction, access and GPU friendliness. Finally, we present an efficient parallel GPU implementation of the algorithms and search structures.

III -Attended Seminars, Workshops, and Conferences

- *SIGGRAPH 2007, 5-9 August 2007, San-Diego, USA.*
- *Eurographics 2007, 3-7 September 2007, Prague, Czech Republic.*