Real-time Rendering of Massive Unstructured Raw Point Clouds using Screen-space Operators

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Abstract
Nowadays, 3D acquisition devices allow us to capture the geometry of huge Cultural Heritage (CH) sites, historical buildings and urban environments. We present a scalable real-time method to render this kind of models without requiring lengthy preprocessing. The method does not make any assumptions about sampling density or availability of normal vectors for the points. On a frame-by-frame basis, our GPU accelerated renderer computes point cloud visibility, fills and filters the sparse depth map to generate a continuous surface representation of the point cloud, and provides a screen-space shading term to effectively convey shape features. The technique is applicable to all rendering pipelines capable of projecting points to the frame buffer. To deal with extremely massive models, we integrate it within a multi-resolution out-of-core real-time rendering framework with small pre-computation times. Its effectiveness is demonstrated on a series of massive unstructured real-world Cultural Heritage datasets. The small precomputation times and the low memory requirements make the method suitable for quick onsite visualizations during scan campaigns.

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.3]: Picture and Image Generation—; Computer Graphics [I.3.7]: Three-Dimensional Graphics and Realism—.

1. Introduction
Acquisition devices, such as mobile or aerial laser scanners, are able to produce massive datasets. The abundance of samples finds a perfect field of application in Cultural Heritage (CH), where both dense and extensive sampling is required. Terrestrial Laser Scanners (TLS) or vehicle based mobile systems (Kinematic TLS) allow us to acquire high quality models of huge CH sites, historical buildings and urban environments. Wide range scanning is increasingly important, since much of CH items revolves around complex modern and ancient cityscapes. Although the typical data representation used in CH is the triangulated mesh, recently there has been a renowned interest towards the use of point clouds, which are easier to create and manage. Given this tendency, CH applications involving point clouds are becoming more and more important [SZW09, DDGM∗04]. In many cases, acquired point clouds consists in an unstructured list of positions of sampled points, without other associated geometrical attributes; for instance, in the last decade the use of unstructured point clouds from moving LIDAR devices has gained a lot of attention in archaeological survey. In addition, due to high acquisition ranges, sampling rates are widely varying, and most datasets are affected by noticeable noise. Thus, fast pre-processing and real-time high-quality rendering of such noisy unstructured point clouds is crucial, especially for quick on-site visualizations during scan campaigns.

Some real-time methods directly draw the points as constant size disks. They don’t fully take into account occlusions, leaving holes in under-sampled areas, producing hard to read images, and requiring color attribute to provide information on surface shape. Other techniques require extensive pre-computations of per-point normal and spatial extent. They provide higher quality rendering, but the pre-processing is time consuming and non-trivial, especially for non-uniformly-sampled massive models. We propose a method for good quality direct rendering of unstructured raw point clouds, which exploits the high performance of GPUs to do all the computations at rendering time, on a frame-by-frame basis. We introduce an on-the-fly visibility estimator, which transforms the point rendering problem into a simpler image infilling problem applied to frame buffer...