ABSTRACT
HIERARCHICAL AND ADAPTIVE FILTER AND REFINEMENT ALGORITHMS FOR GEOMETRIC INTERSECTION COMPUTATIONS ON GPU

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Geometric intersection algorithms are fundamental in spatial analysis in Geographic Information System (GIS). This dissertation explores high performance computing solution for geometric intersection on a huge amount of spatial data using Graphics Processing Unit (GPU). We have developed a hierarchical filter and refinement system for parallel geometric intersection operations involving large polygons and polylines by extending the classical filter and refine algorithm using efficient filters that leverage GPU computing.

The inputs are two layers of large polygonal datasets and the computations are spatial intersection on pairs of cross-layer polygons. These intersections are the compute-intensive spatial data analytic kernels in spatial join and map overlay operations in spatial databases and GIS. Efficient filters, such as PolySketch, PolySketch++ and Point-in-polygon filters have been developed to reduce refinement workload on GPUs. We also showed the application of such filters in speeding-up line segment intersections and point-in-polygon tests. Programming models like CUDA and OpenACC have been used to implement the different versions of the Hierarchical Filter and Refine (HiFiRe) system.

Experimental results show good performance of our filter and refinement algorithms. Compared to standard R-tree filter, on average, our filter technique can still discard 76% of polygon pairs which do not have segment intersection points. PolySketch filter reduces on average 99.77% of the workload of finding line segment intersections. Compared to existing Common Minimum Bounding Rectangle (CMBR) filter that is applied on each cross-layer candidate pair, the workload after using PolySketch-based CMBR filter is on average 98% smaller. The execution time of our HiFiRe system on two shapefiles, namely USA Water Bodies (contains 464K polygons) and USA Block Group Boundaries (contains 220K polygons), is about 3.38 seconds using NVidia Titan V GPU.