

Tree contraction, connected components, minimum spanning trees: a GPU path to vertex fitting

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We consider standard parallel computing operations in the context of algorithms for solving 3D graph problems, which have applications in vertex finding in HEP. Exploiting GPU acceleration for tree accumulation and graph algorithms poses a challenge: GPUs offer extreme computational power and high memory access bandwidth, combined with a fine-grained parallelism that may not fit the irregular distribution of the linked representation of graph data structures. Assuming n vertices, the computation of minimum spanning trees for 2D graphs has efficient $O(n \log n)$ solutions through Delaunay triangulations; these, however, are not applicable for three or more dimensions. General minimum spanning tree computations are limited by lower bounds (Setti and Ramachandran) demanding work linear in the number of edges, quadratic in the number of vertices for dense graphs. Practical efficient implementations for either the Setti and Ramachandran or the Chazelle algorithms have been elusive, and without parallel architecture formulations. We consider first the efficiency of tree accumulation algorithms by Reif and Vishkin. We use tree accumulations as a tool in 3D graph connected components evaluation by combining them with the classical Shiloach-Vishkin algorithm and a randomized tree contraction phase. We also use tree accumulation in an approximation algorithm for minimum spanning trees, comparing it with parallel variations of the Boruvka minimum spanning forest calculation. Minimum spanning trees are at the core of the ZVMST vertex finding algorithm. We discuss implementations for graph connected components and spanning trees calculation on GPU and multi-core architectures.

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