STEVENS INSTITUTE OF TECHNOLOGY 1870

Ph.D. DISSERTATION DEFENSE

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Title:	High-Performance Spectral Algorithms for Hypergraph Compression
Chairperson:	Dr. Zhuo Feng, Department of Electrical and Computer Engineering
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ABSTRACT

The spectral theory has been extensively studied for compressing undirected graphs, including coarsening and sparsification. With the surge of multi-relational datasets, there is increasing pressure to use hypergraphs to capture higher-order relationships among entities within the network. However, spectral methods are less developed for hypergraphs due to the absence of a practical method for computing the hypergraph Laplacian matrix, the lack of a robust method for computing the eigenvalues/eigenvectors of a hypergraph, and the non-linear quadratic operator of hypergraphs. As a result, it is necessary to develop efficient spectral hypergraph algorithms to reduce hypergraph size while preserving spectral properties. This dissertation explores the leverage of the spectral theory to develop hyper/graph compression algorithms, utilizing nearly-linear time methods to identify less spectrally important hyper/edges. Our approach is effective in hypergraph coarsening, and maximum flow computation in undirected graphs.

The first part of this dissertation focuses on a scalable algorithmic framework for spectral coarsening of large-scale hypergraphs by exploiting hyperedge effective resistances. It aims at decomposing large hypergraphs into multiple node clusters with only a few inter-cluster hyperedges and incorporates the latest diffusion-based non-linear quadratic operators defined on hypergraphs. The algorithm further improves the performance by leveraging a strongly-local max-flow-based clustering algorithm for detecting sets of hypergraph vertices that minimize ratio cut.

The second part proposes a practically efficient algorithm for approximating maximum flows in large undirected graphs, based on the recent high-performance spectral graph algorithms. The proposed approach treats the undirected graph as a resistor network and exploits a resistor-network optimization framework that can be further accelerated by leveraging current nearly-linear-time graph Laplacian solvers.

Extensive experiment results demonstrate the effectiveness and efficiency of these algorithms on real-world VLSI design benchmarks, social networks, and other public-domain network cases, and show significant improvement in runtime efficiency and multi-way conductance over existing state-of-the-art algorithms.