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Preconditioning Techniques for Dense Linear Systems

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Dense linear systems arise in a number of applications where one needs to solve a set of integral equations. Since the dense coefficient matrix is never computed and stored explicitly due to prohibitive cost, one must use iterative methods to solve these systems. Matrix-vector products with the coefficient matrix are computed via approximate hierarchical techniques such as the Fast Multipole Method (FMM) which reduce the complexity from $O(n^2)$ to $O(n)$ for a matrix of size n. Unavailability of the coefficient matrix makes it difficult to construct preconditioners for the system.

In this talk, we present techniques to transform the dense linear systems into sparse systems which can then be preconditioned by incomplete factorization techniques. The dense approximate matrix generated by the hierarchical methods is represented as a product of sparse matrices. This fact is exploited to convert the dense linear system into a sparse system. The sparse coefficient matrix of the transformed system is computed explicitly. Preconditioners for the sparse system are computed via incomplete factorizations.

This approach has been successfully applied to capacitance extraction of VLSI circuits in which the charge on a set of conductors is determined by solving a dense linear system that relates known potential on each conductor with the unknown charge distribution. The number of discretization panels on the surface of the conductors determine the size of the system. Non-symmetric systems are obtained when multiple dielectrics are present. We will present numerical experiments to demonstrate the effectiveness of the approach.