PARAGRPH 4 in Introduction

Another solution, pursued in this paper, is to compute multiple SpMVs at once on matrices that have the same sparsity pattern. Obviously not all the applications have such a property. However, important classes of applications such as graph recommendation~\cite{Kucuktunc13-SNAM}, eigensolving~\cite{LOBPCG} and the computation of derivatives for solving systems of PDEs using Radial Basis Function-generated Finite Differences (RBF-FD)~\cite{FLBWSC12} can use multiple SpMVs simultaneously. Since RBF-FD is a mesh-less method, easily handling irregular geometries and local refinement with algorithmic complexity not increasing with dimension as well as high-order derivative approximations, they are rapidly gaining ground in science and engineering modeling communities \cite{Bayona13,CDNT,FoL11,FLBWSC12,SPLM}). As a result, it is of interest to develop an efficient implementation on novel computer platforms for the calculation of derivatives within the context of RBF-FD. This paper investigates the case of approximating four different derivatives, using RBF-FD, for four different functions (a common scenario in 3D fluid dynamics modeling). Since the RBF-FD differentiation matrices approximating the four different derivative operators have an identical sparsity pattern, this leads to the simultaneous execution of 16 SpMVs at a time. Using multiple vectors at a time has been investigated before to densify the computations~\cite{Im01} but, to the best of the authors’ knowledge, this is the first time that the densification comes from adding both vectors and matrices.

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In Section II, we introduce and further motivate the RBF-FD method, giving an example of how calculating the derivatives for a common system of PDEs in fluid dynamics can be expressed as sixteen multiplications of four vectors by four sparse matrices with identical sparsity patterns.

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It also provides the actual performance of the various kernels on multiple classes of matrices, some generated for purpose of analysis, and some extracted from an application of RBF-FD. A performance of 135 Gflop/s is achieved using RBF-FD differentiation matrices. Concluding remarks and perspectives are provided in Section VI.