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Multilevel Solutions, Least Square Extrapolation and a Posteriori Error Estimate

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Abstract: A posteriori error estimators are fundamental tools used to provide confidence in the numerical computation of PDEs. Unfortunately, the main theories of a posteriori estimators have been developed largely in the finite element framework, first for linear elliptic operators and second for non-linear PDEs in the absence of disparate length scales such as boundary layers.
On the other hand, there is a strong tradition in using grid refinement combined with Richardson extrapolation to produce CFD solutions with improved accuracy and, therefore, a posteriori error estimates on coarse grid solutions. But in practice, the effective order of a numerical method often depends on space location and is not accurately satisfied on different levels of grids used in the extrapolation formula. The Richardson extrapolation method then becomes unreliable. We propose a more robust and numerically efficient method that automatically finds the order of a method as the solution of a least square minimization problem on the residual. We introduce a multi-level least square extrapolation method that post-processes several grid solutions to recover accuracy and provide a posteriori error estimate. This method is not restricted to uniform refined grid solutions, nor strictly embedded grid levels. Our least square extrapolation method is a post-processing of data produced by existing PDE codes, that is easy to implement and does not require detailed knowledge of the PDE code itself. This work is a continuation of papers presented at DD13 and DD14 — see references.

[1] M. Garbey and W. Shyy, *A Least Square Extrapolation Method for improving solution accuracy of PDE computations*, J. of Comput. Physic 2003 in press, available on line Feb. 2003.

[2] M. Garbey and W. Shyy: *Error Estimation, Multilevel Method and Robust Extrapolation in the Numerical Solution of PDEs*, to appear in the proceeding of the 14th Int. Conf. On Domain Decomposition.

[3] M. Garbey, *Some Remark on Multilevel Method*, Extrapolation and Code Verification, 13th Int. Conf. on Domain Decomposition DD13, Domain

Decomposition Methods in Science and Engineering, CIMNE, Barcelona, N. Debit et al edt, pp379-386, 2002.

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