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Adaptive Online Multiscale Model Reduction for Heterogeneous Problems in Perforated Domains

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In this work, we develop and analyze an adaptive multiscale approach for Stokes problems in heterogeneous perforated domains. In many applications, these problems have a multiscale nature arising because of the perforations, their geometries, the sizes of the perforations, and configurations. Typical modeling approaches extract average properties in each coarse region, that encapsulate many perforations, and formulate a coarse-grid problem. In some applications,the coarse-grid problem can have a different form from the fine-scale problem, e.g., the coarse-grid system corresponding to a Stokes system in perforated domains leads to Darcy equations on a coarse grid. In this work, we present a general offline/online procedure, which can adequately and adaptively represent the local degrees of freedom and derive appropriate coarse-grid equations. Our approaches start with the offline procedure, which constructs multiscale basis functions in each coarse region and formulates coarse-grid equations. We then develop an adaptive strategy in the online procedure, which allows adaptively incorporating global information and is important for a fast convergence. We present online adaptive enrichment algorithms for the three model problems mentioned above. Our methodology allows adding and guides constructing new online multiscale basis functions adaptively in appropriate regions. We present the convergence analysis of the online adaptive enrichment algorithm for the Stokes system. In particular, we show that the online procedure has a rapid convergence with a rate related to the number of offline basis functions, and one can obtain fast convergence by a sufficient number of offline basis functions, which are computed in the offline stage. To illustrate the performance of our method, we present numerical results with both small and large perforations. We see that only a few (1 or 2) online iterations can significantly improve the offline solution.

References

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