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Operator Theory, Matrix Analysis, Numerical Ranges

We are interested in transport and diffusion problems in heterogeneous media. These problems arise from contaminant flows in the subsurface, heat transfer in two-phase media, stress in composite materials, etc. Our attention is mostly on the mathematical modeling, convergence analysis, and numerical computations.

Consider an elliptic equation in a periodic domain with period size ε. It is known that if ε tends to 0, the solution of the elliptic equation approaches a solution of a simple macroscopic equation. Moreover, a convergence estimate can be derived. Therefore, we would like to ask the same questions for realistic problems. If a mathematical model for a realistic problem is available, is it possible to find a simple macroscopic model so that the solution of the simple model still keeps properties close to those of the original realistic problem when measured on long space-time scales? If yes, can we derive a convergence estimate for the realistic solution? Also is it possible to find a simple way to compute the solution of the original realistic problem?

To answer these questions, some basic tools are necessary, for example, knowledge of partial differential equations and ergodic theory, understanding of functional spaces and homogenization methods, and numerical methods.