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Preserving Structure in the Numerical Simulation of PDEs

Differential equations are ubiquitous in modeling physical phenomenon and more generally in mathematics. On the one hand, studying the intrinsic properties of the operator or of their solutions has given rise to deep results and techniques in analysis and beyond. On the other hand, one may wish to have approximate solutions for the purpose of studying nature, engineering design, or provide some intuition to otherwise abstract objects.

The discretization of differential operators with respect to a small parameter h provides a discrete equation for the solution. Among other things we ask for convergence of the discrete solution to the actual solution as h–>0. However, in practice, h is finite. It turns out that preserving certain structures in the discretization provides great benefits for the approximated solution.

This talk will have two parts:

-1- I will give a short overview of what we mean by structure-preservation in the context of discretization of differential equations.

-2- I will look at the case of evolution PDEs which solutions develop a wide range of scales. I will show that by preserving the operator semi-group structure we may design a computationally efficient method with exceptional resolution properties. I will illustrate this technique with problems from fluid dynamics.