IMACS Workshop on Adaptive Methods for Partial Differential Equations

Summary

This is a request for supplemental support for the IMACS Workshop on Adaptive Methods for Partial Differential Equations to be held at the Fields Institute of Mathematics in Toronto in August, 2002. This workshop is part of a year-long program focusing on numerical computation—the first ever at the Fields Institute. The program recognizes the central importance of numerical analysis in advancing computational science and engineering, and seeks to expand interactions among mathematicians, scientists, and engineers. The requested funds will be used to help defray travel expenses of researchers from the U.S., including invited speakers and young researchers at the graduate or post-doctoral level. We are fortunate to have this opportunity to bring young computational scientists to the prestigious Fields Institute and hopeful that the National Science Foundation will participate.

Program Committee

- Paul F. Fischer, Argonne National Laboratory, U.S.A
- Joseph E. Flaherty, Rensselaer Polytechnic Institute, U.S.A.
- Benqi Guo, University of Manitoba, Canada (Co-Chairman)
- Kenneth R. Jackson, University of Toronto, Canada (Co-Chairman)
- Robert D. Russell, Simon Fraser University, Canada

Introduction

The past five decades has witnessed a spectacular advance in the application of computational mathematics to problems of importance to science, industry, and society. While much of this advance has been enabled by increases in raw computing power, one can readily argue that advances in numerical algorithms have shared equally in enabling the solution of ever more challenging problems. An obvious example of this is in the solution of linear systems arising in the solution of partial differential equations (PDEs), where the computational effort for the solution of an n-point discretization of a three-dimensional elliptic problem has been reduced from $O(n^{5/3})$ to $O(n)$, as we've moved from classic relaxation techniques to modern multigrid and domain-decomposition-based iterative methods. Clearly, $O(n)$ is a lower bound complexity estimate. If algorithm development is to keep apace of hardware improvements, it will need to do so through a reduction in n. For many problems, adaptivity offers the potential for orders-of-magnitude reduction in computational cost through a reduction in the number of points required for a given accuracy.

Adaptive methods for partial differential equations (PDEs) are the most effective computational approach for a large class of PDEs that arise in many important applications in science and engineering such as structural mechanics, combustion, micromagnetics (at nanoscales), design optimization, biofluid dynamics, and turbulence. While this area has grown steadily during the past two decades, the many challenges faced in the development of adaptive methods, particularly on large-scale parallel architectures, have kept them from becoming ubiquitous. The development of adaptive methods requires rigorous numerical analysis to provide sharp error estimates for difficult nonlinear problems. In addition, it calls for flexible variable-order discretizations that can achieve optimal rates of convergence, a correct and complete description of complex geometries in order that computational boundaries are adequately described upon mesh refinement, and high-level software that is flexible and capable of efficient data management on distributed-memory parallel computers consisting of thousands of processors. Most importantly, because of the challenging nature of the underlying mathematics and science, this development effort cannot take place in a vacuum, but must rely on input from application scientists in the specific domain of interest.

This workshop will bring together leading researchers from around the world to address outstanding numerical, computational, and computer science questions in the development of adaptive methods for PDEs coming from a broad range of scientific and engineering applications. The meeting will foster collaborations and stimulate research among this diverse group of individuals that will help to push the development and dissemination of adaptive methods and software and to realize their implementation on modern high-performance computers. Students and young researchers in attendance will make personal contact with numerical analysts and scientists whose expertise and guidance will help them decide whether their particular application can exploit currently available adaptive software, or whether a significant development effort is required.

The following table gives a (nonexclusive) list of discussion topics.

- A posteriori error estimation
- Adaptive h–p refinement
- Adaptivity with complex geometry
- Implementation of adaptive codes
- Moving mesh techniques and applications
- Adaptive spectral methods
- Nonlinear analysis

- Adaptive modeling
- Applications of adaptive methods

Recent Meetings

The planned meeting is the eighth in a series of IMACS PDEs conferences, dating back to 1975, and the first to focus specifically on adaptive methods. Recent workshops on this topic include the *Structured Adaptive Mesh Refinement Grid Methods Workshop*, held at the IMA in March 1997; the *Adaptive Methods for Differential Equations Workshop*, held in Stockholm in March 1998; the *GAMM Workshop on Adaptive Methods - Error Estimators* in Kiel in January 2000; and the *Adaptive and High-Order Methods Workshop*, held at NCAR in February 2002. The NCAR workshop focused on fluid mechanics, with a strong emphasis on spectral methods, while the GAMM workshop focussed on error estimation and numerical analysis. Both were more limited in scope than the current proposal. Several recent developments warrant revisiting adaptive methods since those held in the late '90s. In particular, discontinuous Galerkin methods (Cockburn) have undergone significant development in this time, and wavelet-based methods (Vassilyev) are beginning to mature into feasible approaches. In addition, the spread of terascale platforms, and associated increases in attainable problem complexity, are making increased demands on the need and the sophistication of adaptive methods at this time.

The topic of adaptive methods takes on particular relevance at present in light of current interests within the NSF in the simulation of multiscale phenomena and the advent of initiatives in DOE relating to the development of adaptivity-based software tools targeted for terascale computing platforms.

Structure of the Program

The workshop will consist of eight invited and roughly thirty contributed lectures by leading and upcoming researchers in fields that span numerical analysis, computational science, computer science, and engineering. Invited lectures will be 45 minutes each, and contributed talks will be 30 minutes each. The lists of invited speakers is given below.

- Mark Ainsworth, Strathclyde University, Scotland
- Ivo Babuska, University of Texas at Austin, U.S.A.
- Martin Berzins, University of Leeds, U.K.
- Anne Bourlioux, University of Montreal, Canada

- Bernardo Cockburn, University of Minnesota, U.S.A.
- Leszek Demkowicz, University of of Texas at Austin, U.S.A.
- Oleg Vassilyev, University of Missouri, U.S.A.
- Jinchao Xu, Penn State University, U.S.A.

Publicity and Recruitment

The workshop is one of the many activities in the Fields Institute's year-long program in numerical computation and an announcement has been posted at the following URL.

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www.fields.utoronto.ca/programs/scientific/01-02/
                    numerical/adaptive/index.html#papers
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The workshop is juxtaposed to two other Institute workshops of relevance to this particular field, namely, *The Short Course on the Numerical Solution of Advection-Diffusion-Reaction Equations*, and *The 2002 Workshop on the Solution of Partial Differential Equations on the Sphere*. We expect that some attendees will stay through the course of two or more of these workshops. Colleagues around the world have been contacted by members of the scientific committee regarding the Adaptive Methods for PDEs Workshop via email, and we expect to have about 40 attendees in total. Some of the travel funds coming from NSF will be used to support young researchers from the U.S. at the Ph.D. and post-doctoral level who would otherwise not be able to attend. Particular effort will be made to bring researchers from traditionally underrepresented groups, such as women, minorities, and persons with disabilities.