Curriculum Vitæ

Name: Kurt Otto
Date of birth: September 19, 1962

Professional preparation

In August 1989, I received an M.Sc. degree in Engineering Physics from Uppsala University. From September 1989 until May 1993, I was a graduate student at the Department of Scientific Computing, Uppsala University. In May 1993, I received a Ph.D. in Numerical Analysis. From October 1994 through June 1995, I visited the Computer Science Dept., Univ. of Maryland at College Park, in the position of Postdoctoral Research Associate. I was involved in a project concerning high-order discretizations and iterative solution of the Helmholtz equation in underwater acoustics.

Degrees

- M.Sc. in Engineering Physics, specialization in Scientific Computing, Uppsala University, August 1989.
- Ph.D. in Numerical Analysis for my dissertation on *Construction and Analysis of Preconditioners for First-order PDE*, Uppsala University, May 1993.
- Docent in Numerical Analysis, Uppsala University, June 1998.
- Laborator in Computational Wave Propagation, Swedish Defence Research Agency, May 2002.

Awards

1. Third place in the student paper competition at the *Copper Mountain Conference on Iterative Methods*, April 1-5, 1990, Copper Mountain, CO, USA.
2. The Oscar Prize 1997 from Uppsala University.

Graduate student supervision

1. Principal advisor for Elisabeth Larsson, who received the degree of Doctor of Technology in Numerical Analysis (on May 19, 2000) for her dissertation on *Domain Decomposition and Preconditioned Iterative Methods for the Helmholtz Equation.*

2. Advisor for Malin Ljungberg, who received the degree of Licentiate of Technology in Scientific Computing (on May 23, 2003) for her dissertation on *Handling of Curvilinear Coordinates in a PDE Solver Framework*.

3. Principal advisor for Elena Sundkvist, who was admitted in July 2001 to the Ph.D. program.

Affiliations

1. Postdoctoral Research Associate (from October 1994 through June 1995) at the Dept. of Computer Science, University of Maryland at College Park, MD, USA.

2. Universitetslektor (from July 1995 through December 1999) at the Dept. of Scientific Computing, Uppsala University.

3. Förste forskare (from January 2000 through April 2002) at the Dept. of Underwater Acoustics, Swedish Defence Research Agency, Stockholm.

- Laborator (from May 2002) at the Dept. of Underwater Acoustics, Swedish Defence Research Agency, Stockholm.

- Forskare (part-time; 20% from February 2000) at the Dept. of Scientific Computing, Information Technology, Uppsala University.

Publications

Refereed

[1] K. Otto and M. Thuné, *Stability of a Runge–Kutta method for the Euler equations on a substructured domain*, SIAM J. Sci. Statist. Comput., 10 (1989), pp. 154–174.

[2] S. Holmgren and K. Otto, *Iterative solution methods and preconditioners for block-tridiagonal systems of equations*, SIAM J. Matrix Anal. Appl., 13 (1992), pp. 863–886.

[3] K. Otto, *Construction and Analysis of Preconditioners for First-order PDE*, Ph.D. thesis, Dept. of Scientific Computing, Uppsala Univ., Uppsala, Sweden, 1993.

[4] S. Holmgren and K. Otto, *Semicirculant preconditioners for first-order partial differential equations*, SIAM J. Sci. Comput., 15 (1994), pp. 385–407.

[5] L. Hemmingsson and K. Otto, *Analysis of semi-Toeplitz preconditioners for first-order PDEs*, SIAM J. Sci. Comput., 17 (1996), pp. 47–64.

[6] S. Holmgren and K. Otto, *Semicirculant solvers and boundary corrections for first-order partial differential equations*, SIAM J. Sci. Comput., 17 (1996), pp. 613–630.

[7] K. Otto, *Analysis of preconditioners for hyperbolic partial differential equations*, SIAM J. Numer. Anal., 33 (1996), pp. 2131–2165.

[8] E. Mossberg, K. Otto, and M. Thuné, *Object-oriented software tools for the construction of preconditioners*, Sci. Programming, 6 (1997), pp. 285–295.

[9] M. Thuné, E. Mossberg, P. Olsson, J. Rantakokko, K. Åhlander, and K. Otto, *Object-oriented construction of parallel PDE solvers*, in Modern Software Tools for Scientific Computing, E. Arge, A. M. Bruaset, and H. P. Langtangen, eds., Birkhäuser, Boston, MA, 1997, pp. 203–226.

[10] S. Holmgren and K. Otto, *A framework for polynomial preconditioners based on fast transforms I: Theory*, BIT, 38 (1998), pp. 544–559.

[11] ——, *A framework for polynomial preconditioners based on fast transforms II: PDE applications*, BIT, 38 (1998), pp. 721–736.

[12] K. Otto and E. Larsson, *Iterative solution of the Helmholtz equation by a second-order method*, SIAM J. Matrix Anal. Appl., 21 (1999), pp. 209–229.

[13] M. Thuné, K. Åhlander, M. Ljungberg, M. Nordén, K. Otto, and J. Rantakokko, *Object-oriented modeling of parallel PDE solvers*, in The Architecture of Scientific Software, R. F. Boisvert and P. T. P. Tang, eds., vol. 188 of IFIP Conf. Proc., Kluwer Acad. Publ., Norwell, MA, 2001, pp. 159–174.

[14] K. Åhlander and K. Otto, *Software design for finite difference schemes based on index notation*, Future Generation Comput. Syst., 22 (2006), pp. 102–109.

[15] M. Ljungberg, K. Otto, and M. Thuné, *Design and usability of a PDE solver framework for curvilinear coordinates*, Adv. Engrg. Software, 37 (2006), pp. 814–825.

[16] K. Otto and E. Larsson, *A flexible solver of the Helmholtz equation for layered media*, in Proc. ECCOMAS CFD Conf. 2006, P. Wesseling, E. Oñate, and J. Périaux, eds., Tech. Univ., Delft, The Netherlands, 2006, pp. 8.

Unrefereed

[1] K. Otto, *Iterative solution of the Helmholtz equation by a fourth-order method*, Boll. Geof. Teor. Appl., 40:1 suppl. (1999), pp. 104–105.

[2] I. Karasalo and K. Otto, *A numerical study of the acoustic field in a fiber-optic hydrophone*, Meth. Rep. FOA-R–00-01780-409–SE, Division of Sensor Technology, Swedish Defence Research Agency, Linköping, Sweden, 2000.

[3] ——, *Acoustic scattering from submerged elastic objects*, Meth. Rep. FOI-R–0307–SE, Division of Systems Technology, Swedish Defence Research Agency, Stockholm, Sweden, 2001.

[4] K. Otto, *A tensor framework for preconditioners based on fast transforms*, BIT, (submitted 2003).

Conference contributions

Five invited talks, 18 talks, and two poster presentations at international conferences in eleven different countries. A comprehensive list of my contributions could be compiled from `http://www.it.uu.se/research/group/anla/publ.ps`

Previous research accomplishments

The state of the art for solving linear systems of equations arising from discretizations of wave propagation problems is to employ some Krylov subspace method. In order to achieve an acceptable rate of convergence and, more importantly, a short total execution time, it is crucial to construct effective, parallelizable preconditioners. That was the main topic in my Ph.D. thesis. Previously, we have designed preconditioners [2] based on the fast Fourier transform, which have been successfully applied to second-order accurate discretizations of first-order systems of PDEs [6] on a single domain, and in a domain decomposition setting by Hemmingsson. The solution procedures are highly parallelizable, and have already from the beginning been implemented (in collaboration with my colleagues Drs. Holmgren and Larsson) on a variety of parallel computer architectures. Moreover, the convergence properties have been thoroughly analyzed [7, 4, 5]. The preconditioning technique has been generalized to several fast trigonometric transforms [10], which resulted in favorable convergence properties for high-order discretizations of a scalar first-order PDE [11] and for a second-order discretization of the Helmholtz equation [12].

Future research plans

Numerical algorithms and computer technology have developed to a point where computational methods are being used routinely for many acoustical applications. However, even using the powerful parallel computers available today, current methodologies and software are not sufficiently good for the study of phenomena that require very high resolution. Such phenomena occur in underwater acoustics, especially for high frequencies and over long propagation ranges. Additional difficulties when modeling sound propagation in the Swedish littoral environment are the seasonal variations and the shallow waters, which lead to a strong influence from the seabed on the sound field in the water. We intend to model sound propagation in waveguides consisting of water, soft sediment, hard sediment or bedrock layers. The primary objectives are to design efficient parallel numerical algorithms, and supporting parallel software tools for such applications. However, our numerical algorithms and software tools will *not* be limited to hydroacoustic applications. They will be useful also for wave propagation problems in electromagnetics and geophysics.

Our solution approach is to couple the solution of the Helmholtz equations for the interior domains (water and sediment layers) to an integral equation solution for the exterior domain (solid layer). These equations will be discretized by a hybrid method combining high-order finite difference and finite element methods in a domain decomposition setting. The result is systems of linear equations, where the coefficient matrices (or rather tensors) are large, complex, indefinite, and ill-conditioned. We use a tensor notation [4] for these linear operators. Our motivation for this is that it considerably facilitates the construction of the numerical algorithms as well as the design [14] and implementation of our object-oriented software tools. The standard matrix notation, which has been long prevailing in the numerical linear algebra community, actually makes designing and coding unnecessarily complicated!

We take the *design and analysis of numerical algorithms* and the *design and implementation of parallel software tools* simultaneously into account. The rationale for this is twofold. Firstly, for the study of numerical algorithms, it is necessary to carry out experiments on high-performance computers. In the absence of relevant software tools, the construction and modification of the programs for these experiments will be a bottle-neck. Secondly, on successful completion of the software tools, the new numerical techniques will be available to application specialists.

This research spans over physical modeling, mathematical modeling, numerical methods, design and implementation of object-oriented software, and parallel computing. I will lead these research activities within a group primarily consisting of myself, Dr. Elisabeth Larsson, Elena Sundkvist and Malin Ljungberg (my current graduate students).